THE

GEOLOGICAL MAGAZINE.

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No. XII.—DECEMBER, 1894.

A RETROSPECT OF MORE THAN THIRTY YEARS.

IT is now more than thirty years ago since, with my friend Professor T. Rupert Jones, F.R.S., we commenced to Edit the GEOLOGICAL MAGAZINE, Messrs. Longmans & Co. being our publishers.

Out of the long list of distinguished Supporters and Contributors to the GEOLOGICAL MAGAZINE published in 1864, I rejoice that twenty-four ORIGINAL NAMES still remain, after more than thirty years, namely:—The Duke of Argyll; the Earl of Ducie; Sir Archibald Geikie; the Right Hon. Thomas Huxley; Sir John Evans; Prof. Prestwich; Prof. T. G. Bonney; Prof. Wiltshire; Prof. Boyd-Dawkins; Prof. Alphonse Milne-Edwards; Prof. Dr. A. Fritsch; Prof. A. von Koenen; Prof. E. Hull; Prof. H. G. Seeley; Mr. R. Etheridge; Mr. William Carruthers; Mr. William Whitaker; Rev. O. Fisher; Mr. James Carter; Mr. James Powrie; Mr. R. H. Valpy; Mr. G. C. Churchill; Mr. R. F. Tomes; and Mr. E. C. H. Day.

To my regret Prof. Rupert Jones retired from the Editorship in June, 1865. After that date, aided by Prof. John Morris (since deceased), and by my colleagues, Mr. R. Etheridge, Mr. Wilfrid Hudleston, and Dr. G. J. Hinde, the MAGAZINE has enjoyed an uninterrupted existence and a well-earned position as a scientific journal.

Messrs. Longmans relinquished the publication in 1865, but it was at once taken up by Messrs. Trübner & Co., who successfully maintained its issue for 25 years, until 1890, when their business was absorbed into that of Messrs. Kegan Paul, Trench, Trübner, and Company (Limited). Now, after a further term of four years, Messrs. Kegan Paul & Co. have kindly allowed me to take the GEOLOGICAL MAGAZINE into my own hands. I embrace the opportunity, therefore, to express to them my sincere thanks for the uniform kindness and courtesy with which they have treated the Editor during the period of their administration, and especially at this epoch in the history of the MAGAZINE.

After the issue of the present Number of the GEOLOGICAL MAGAZINE, Messrs. Dulau and Company, 37, Soho Square, W., have consented to act as my publishers, and I trust to obtain the continued support of my geological friends who have heretofore aided me, both by their contributions and subscriptions, for so many years past.

HENRY WOODWARD.

129, BEAUFORT STREET, CHELSEA, S.W.

ORIGINAL ARTICLES.

I.—Contributions to our knowledge of the Genus *Cyclus*, from the Carboniferous Formation of various British Localities.

By Henry Woodward, LL.D., F.R.S., Pres.Geol.Soc.,
of the British Museum (Natural History).

(PLATE XV.)

THE curious little shield-like Crustaceans, known under the generic name of *Cyclus*, were first noticed by de Koninck in 1841, and have been subsequently figured and described by various authors, but their exact systematic position has never been clearly understood owing to the absence of appendages or other indications by which their affinities might be satisfactorily ascertained.

In 1868 I gave a description, with figures, of two species:[1] one of which, the *Cyclus radialis*, had been previously noticed by de Koninck[2] and Phillips[3]; the other, *C. Rankini*, was then first made known.

In 1870, under the title of "Contributions to British Fossil Crustacea,"[4] I redescribed the above-named species, and added *Cyclus bilobatus*, *C. torosus*, *C. Jonesianus*, *C. Wrightii*, *C. Harknessi*, *C.* (*Halicyne*) *laxus*,[5] *C.* (*Halicyne*) *agnotus*.[5]

The next record of the genus is to be found in the fifth part of my Monograph of British Fossil Crustacea[6] of the order Merostomata, which records and figures the then known seven British species of *Cyclus*, but adds no new forms.

In 1883 Mr. B. N. Peach, F.R.S., L. and E., F.G.S., published an account of *Cyclus testudo*, from the Carboniferous series of Langholm,[7] to which reference will again be made later on.

In 1893 I noticed a new British species of *Cyclus*,[8] discovered by Mr. George Scott in the "Gannister seam" of the Lower Coal-measures, Old Clough Colliery, Bacup, Lancashire, which I named *Cyclus Scotti*.

In the same year Mr. F. R. Cowper Reed, B.A., F.G.S., of Trinity College, Cambridge, gave a description of what he deemed to be probably a new species of *Cyclus*,[9] from the Carboniferous Limestone of Settle, Yorkshire, near to, but not identical with, *C. Harknessi*, which he named *C. Woodwardi*.

[1] British Association Reports, Norwich, 1868, 4th Report on Fossil Crustacea, pp. 72–75, pl. ii. figs. 1 and 2.

[2] L. G. de Koninck, Descript. des Animaux Foss. Terr. Carb. de Belg. Liége, 1842, p. 591, pl. lii.

[3] J. Phillips, Geol. Yorksh. vol. ii. p. 240, t. xxii. fig. 25, 1829.

[4] Geol. Mag. 1870, Vol. VII. Pl. XXIII. Figs. 1–7, pp. 554–560.

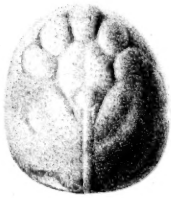
[5, 5] These last-named species are not British, and had been previously described by Prof. Hermann von Meyer, in the Palæontographica, 1847, vol. i. p. 134, under the genus *Halicyne*. They are from the Muschelkalk of Rottweil in Germany. Goldfuss originally figured *Halicyne* as *Olenus serotinus* (Petrefactenkunde), afterwards von Münster referred it to *Limulus* (Beiträge, 1841, Bd. i. t. v. f. 1).

[6] Palæontographical Society, 1878, vol. xxxii. pp. 248–255, pl. xxxii. figs. 42-49.

[7] See Trans. Roy. Soc. Edinburgh, 1883, vol. xxx. pl. xxviii. figs. 9–9*d*, p. 227.

[8] See Geol. Mag. 1893, Decade III. Vol. X. (Woodcuts A, B), p. 28.

[9] *Ibid.* pp. 64–66 (with a Woodcut).



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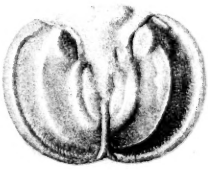

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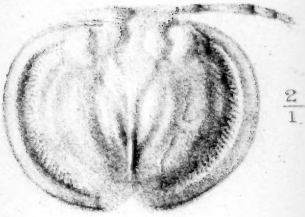

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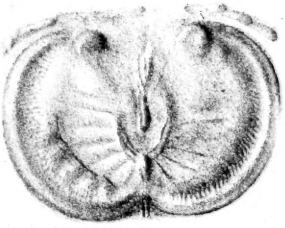

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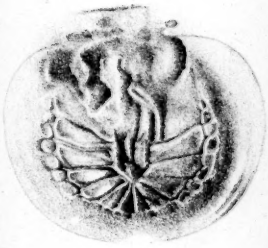

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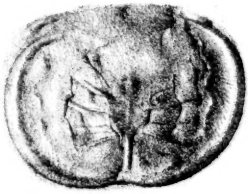

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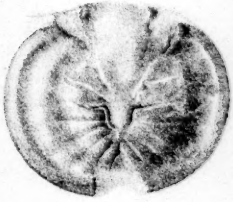

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H.C.&G.M. Woodward del. et lith. West, Newman imp.

Cyclus: Carboniferous.

Having, through the kindness of Prof. John Young, M.D., F.R.S.E. (Regius Professor of Natural History in the University of Glasgow), and Mr. John Young, LL.D., F.G.S., of the Hunterian Museum of the University of Glasgow, been allowed to examine and figure another of the late Dr. Rankin's specimens from Carluke—now preserved in the Museum of the University (Plate XV. Fig. 8)—and being also in possession of a long series of specimens obtained by the late Mr. Henry Johnson, C.E., F.G.S., of Dudley,[1] from the "Pennystone ironstone," over the thick coal of the Staffordshire Coal-field, at Coseley, near Dudley, I am desirous once more to call attention to these very singular little Arthropods.

Fig. 1.—*Cyclus Woodwardi*, Reed. The original specimen is in the Woodwardian Museum, Cambridge, and was obtained from the Carboniferous Limestone, Settle, Yorkshire. Magnified $\frac{3}{1}$ nat. size.

By far the most important contribution to the genus *Cyclus* recently published is to be found in the paper by Peach, entitled "Further Researches among the Crustacea and Arachnida of the Scottish Border."[2] These specimens, writes Peach, "occur chiefly as flat discs, or dome-shaped masses of radiating calculi which have coalesced into a polygonal mosaic of calcareous plates. They vary from 3 mm. to 10 mm. in diameter." . . . . "Being embedded in shale they are more or less flattened, and apparently much in the same condition as the *Cyclus Rankini* described by Woodward as having been obtained from the Carboniferous (shales) of Carluke." They are considered by the author to belong to one species, which is, he thinks, different from any yet described. "A few of the specimens exhibit the dorsal shield, which is plain or slightly embossed; while others only show the dorsal aspect of the borders, the rest of the upper surface being broken away, exposing the ventral or sternal arches, which radiate much as in *Cyclus Rankini*." . . . . "From the fact that several of the Survey specimens exhibit limbs, the radiating lines of the sternum are most probably the divisions between the coxæ, so that I am inclined to differ from Woodward and to look upon the opposite end to what he does as being the anterior." Then follows the specific description of *Cyclus testudo*, Peach, from the Calciferous Sandstone series, Langholm.

In October, 1886, I became aware, from a study of Mr. Henry Johnson's collection of *Cyclus*, obtained from the clay-ironstone

[1] Purchased by the British Museum in 1886.

[2] Trans. Roy. Soc. Edinburgh, 1883, vol. xxx. p. 511, pl. xxviii. figs. 9 and 9*a*, *b*, *c*, *d*.

nodules of the Coal-measures, Coseley, Staffordshire, that the form which I had described in 1868 as *Cyclus Rankini*, from Carluke, and which differed in so very remarkable a manner from all the other carapaces referred to that genus from the Carboniferous Limestone, was really the *underside* of a *Cyclus* from which the shield or carapace had been removed. Unfortunately at that time I had not seen Mr. B. N. Peach's paper, nor was I aware that he had written upon the genus, until my paper on *Cyclus Scotti*, in 1893, was in print, when I added a note apologising for having overlooked it.[1]

To Mr. Peach, therefore, belongs the merit of having been the first to explain (in 1883) the true nature of the peculiar structure observed in *C. Rankini*. But the interpretation put upon the genus by Mr. Peach remains to be considered. And here let me express my thanks to Sir A. Geikie, the Director-General, for granting me permission to study the original specimens of *Cyclus*, described by Mr. Peach, which Mr. J. G. Goodchild, in charge of the Survey Collection in Edinburgh, has most kindly forwarded to me.

An examination of these specimens at once reveals the extreme difficulties which Mr. Peach encountered in endeavouring to decipher these very obscure little organisms, most of which have had the details of their structure almost entirely obliterated by deposits of globular or orbicular calcite.[2]

I was fortunate also in obtaining twenty specimens of *Cyclus testudo* from Eskdale, early in the present year, from Mr. T. Stock; and, although most of these were similarly obscured by calcite-deposits, I have obtained some good results, which I will presently refer to.

The best preserved specimens which Mr. Peach had the good fortune to secure, not only show traces of an upper dorsal shield, but also evidence of the ventral surface with its sterna and radiating apodemata, as figured by me, in 1868, in *C. Rankini* from Carluke, and also in our present Plate XV. Fig. 8. Thus the enigmatical *Cyclus Rankini*—as Peach points out, and as the specimens here figured conclusively prove—is in reality the sternal surface of a *Cyclus*, the dorsal shield of which may, or may not, be known.

So far, we are in general agreement; but when Mr. Peach proceeds to suggest that I have mistaken the *anterior* for the *posterior* end of these carapaces, I am at once at issue with him, and can only conclude that the "globular calcite" has obstructed his clearer vision. Nor is it necessary to institute any very lengthy comparisons with other forms in order to ascertain, as in the famous Skye-terrier controversy, "which is his head and which is his tail." We are, fortunately, not dependent upon the Langholm specimens alone for settling this fundamental point, for in the numerous and beautifully preserved examples from Mr. Henry Johnson's collection we have evidence enough to establish our position beyond a doubt.

[1] See Geol. Mag. 1893, Dec. III. Vol. X. footnote, p. 29.

[2] See note, p. 482, on globular calcite, on a new species of *Eurypterus* from Eskdale, by H. Woodward, Geol. Mag. 1887, Dec. III. Vol. IV. pp. 481–484, Pl. XIII.

Without maintaining that the pair of large rounded prominences, observable in most of the specimens near the anterior border, are eyes, there is evidence both in Figs. 7 and 8, Pl. XV., of the presence of much smaller, and probably stalked, eyes near the front of the head. The evidence of antennæ-like organs, *in situ*, attached to the part which I designate as *the front* of the shield (represented on Plate XV. Figs. 4, 5, and faintly on Fig. 6), seems to me conclusive that this *front*, or *upper border*, as figured by me, is indubitably the head.

Mr. Peach mentions that where the dorsal shield, in his *Cyclus testudo*, "has been broken away, so as to expose the interior of the sternal portion to view, six triangular plates on each side, divided from each other by deep sulci, are seen to converge upon an oval sternum." These plates, he considers, "are the coxæ of limbs."

In discussing the question of the anterior and posterior ends of *Cyclus*, as raised by Peach, the following points must be taken into consideration :—

1. The large pair of jointed appendages at one end, when taken in conjunction with the entire absence of any prolongation of the body beyond the circular shield at either end, suggests that this is the head, and that these appendages represent a pair of swimming antennæ (ant. 2), similar to those of the Phyllopoda.

2. This is further strengthened by the arrangement of the radiating ventral plates at the opposite end of the body, which Peach suggests are enlarged coxæ. If the homology be the true one, which seems probable, then a comparison either with Arachnida or Crustacea, results in the same conclusion, for, in any of these Arthropods, where the limbs converge towards the mouth, or towards the sternum, we find them tending to meet in the middle ventral line, *behind* these structures, and *not in front*, as would be the case in *Cyclus* if Peach's view as to the anterior end of the body were the right one.

3. The *Eye*.—A (paired) small appendage, having somewhat the form of a stalked eye, but showing no facets, is present near the anterior margin of the shell (see Pl. XV. Figs. 7, 8).

Appendages.—The first visible appendages consist of one large jointed pair, extending outwards from the anterior end of the carapace. They suggest, from their position and development, the second pair of antennæ of the *Nauplius*-stage of the Phyllopoda, or of the adult *Cladocera*. No special mouth-parts are visible.

The remaining appendages, which possibly represent both the jaw-parts and anterior thoracic limbs of the higher Crustacea, appear to be 6–7 in number, each of which was provided with a greatly-developed basal joint radiating outwards from the mid-line, and probably had a wide attachment, which may account for their remaining *in situ*. The enlarged joints of the legs pressed against one another, and covered the ventral surface of the body everywhere, save in the centre, which was occupied by a V-shaped plate, towards the pointed extremity of which all the basal joints of the limbs converge. Distally each limb presents two small plates. The rest of the limb is lost in most specimens.

One specimen, however (discovered amongst those obtained by Mr. Stock from Eskdale), besides exhibiting a number of fragments of appendages, scattered irregularly over the surface of the matrix, shows one of the middle limbs in position, still attached to a shield

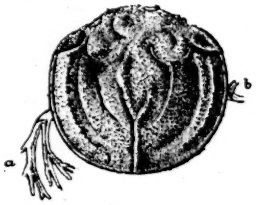


Fig. 2.—*Cyclus testudo*, Peach; Langholm. Enlarged 4 times natural size.
a. One of the biramous swimming-feet which remains attached *in situ*.[1]
b. Base of another appendage, broken off close to the edge of the shield.

of *Cyclus testudo*. This limb is a typical biramous appendage, such as we find in the lower Crustacea, and persisting as the swimmerets in the Decapoda; that type of limb, in fact, which is generally believed to have been the most primitive form, and which is only a slight modification of the typical Phyllopod limb. The numerous broken fragments of appendages scattered over the surface of the matrix appear to have been of the same kind. We may, therefore, conclude it is most probable that the oral and post-oral appendages of *Cyclus* were all of the same type, *i.e.* simple swimming-legs.

The V-shaped median plate between the bases of the appendages must either be the coalesced sternites, or an enormously developed labrum. Against the first view we have the fact that this structure is apparently continued without a break up to the anterior margin of the ventral surface, thus giving no place for the mouth.

If, as the presence of the large antennæ and the swimming-legs prove, *Cyclus* is a Crustacean, then we should naturally expect to find a labrum; and as there is no other median-lobe-like development of the ventral integument, we must, I think, conclude that the structure represents an enormously developed labrum, and that the mouth opened at the posterior extremity of that structure —an exaggeration of what is met with in the Cladocera, where the mouth opens well back in the shell under cover of a great labrum. This would be further strengthened by the convergence of the bases of the limbs towards its posterior border, a condition similar to that met with in *Limulus* (and supposed by Bernard to have been the primitive condition of the jaw-parts of all Crustacea), these bases serving probably, as in *Limulus*, as masticatory organs.

Affinities.—The presence of antennæ and biramous swimming-legs prove undoubtedly that *Cyclus* was a Crustacean. The large size of the former and the homogeneous nature of the rest of the appendages (all biramous swimming-legs, with possibly masticatory

[1] The branching of the two rami may be due to rod-like deposits of lime in a paddle-shaped fin, two such structures being attached to each limb, representing the endopodite and exopodite. A slight indication of this is visible in the specimen.

bases), taken in connection with the large, slightly-bivalved carapace, suggest that it is an Entomostracan and probably one of the Phyllopoda, with a broad cephalic carapace like that possessed by *Apus* and by *Daphnia*; with large swimming second antennæ like the latter, and possibly with a pair of stalked eyes. *Cyclus*, however, differs from the Cladocera in being flattened dorso-ventrally, and from the lowest Crustacea in not apparently possessing any true jaw-parts—the head, with the labrum and mouth, being bent further back than in the living Entomostraca. These differences may either indicate very lowly characters or very much specialized ones. Two views suggest themselves:—

(1) That these animals were small, free-swimming Phyllopods, with expanded cephalic shield, swimming second antennæ, and biramous limbs, the bases of which served as masticatory organs, no true jaws having yet been developed; the backward position of the mouth may have been brought about in order to allow as many appendages as possible to serve as jaws, as is seen in *Limulus*. Or, possibly, the beast could attach itself like a living *Daphnia* by a cement gland on the dorsal side of the head, in which case it might be an advantage to have the mouth as near the freer end as possible and close to the swimming-legs, which were, by their movements, producing the foot-currents.

(2) The other view is that these animals were ecto-parasitic Phyllopods, although they had not lost their power of free-movement, yet had become specialized in the form of their body, which is flattened ventrally and only slightly convex above, the whole animal being expanded horizontally, unlike most other Phyllopods. This view might account for the two large round structures seen on the ventral surface (Pl. XV. Fig. 8), situated one on either side of the body, and close to the anterior margin of the shell. These might possibly represent a pair of ventral suckers, such as are seen in the modern fish-lice; these structures, whatever they may be, are evidently enormously developed, and possess great muscles, which produce prominent modifications of the dorsal shield, where they are attached (Pl. XV. Figs. 3–5). The great labrum might possibly represent the suctorial tube of *Argulus*, under cover of which are concealed the reduced mandibles, etc.

Some of the specimens show curious oblique scars on the coxæ of the legs, which may indicate the points of attachment of spines or setæ to enable the parasite to stick to its fishy host.

The following notes refer to the specimens figured on Plate XV.

1.—Cyclus Jonesianus, H. Woodward. Pl. XV. Figs. 1*a*, 1*b*. × 3 times natural size.

Cyclus Jonesianus, H. Woodw., 1870. Geol. Mag. Vol VII. pp. 557–558, Woodcut, Figs. 1 and 2.

Cyclus Jonesianus, H. Woodw., 1878. Mon. Pal. Soc. vol. xxxii. Fossil Merostomata, part v. p. 254, pl. xxxii. figs. 46*a*, *b*.

I was at first inclined to the opinion that the specimen of *Cyclus* lent to me by my friend Dr. John Young of Glasgow (see Pl. XV. Figs. 1*a*, 1*b*), was a new species; but after having carefully compared

it with that already figured in this MAGAZINE (1870, Woodcut, p. 558), from the collection of Mr. Joseph Wright of Belfast, and obtained by him from the Carboniferous Limestone of Little Island, Cork, and, making allowance for some slight variation between the two specimens, due to their different state of preservation, I am compelled to conclude that they are both referable to the same species, namely, *C. Jonesianus*.

Dr. Young's specimen measures 8 millimètres in length, 7 mm. in breadth, and 4mm. in height. The carapace, which is finely granulated all over its surface, is divided along the anterior border into five rounded lobes of nearly equal size, forming a semicircle, reaching almost to the margin of the shield. The middle area of the carapace, enclosed by these five encircling lobes, is divided down the centre by the dorsal line, thus forming a pair of oblong, somewhat pentagonal lobes, separated only by the median line; behind these, again, is a lesser unpaired subtriangular lobe, with its base directed forwards and having a raised rounded boss in its centre. The hinder and greater half of the carapace is occupied by two large lobes, forming together a semicircle, but divided down the mesial line by the well-marked dorsal ridge which extends to the posterior border. The upper and more central part of each lobe is marked by a slight semicircular furrow dividing faintly this inner and more elevated portion of the shield from the lower and outer encircling border. The two minute depressions observed in Mr. Wright's specimen, one on either side of the dorsal ridge, at the vertex of the shield, are not visible in Dr. Young's specimen, being probably covered by a shelly layer, which had been removed in Mr. Wright's Irish example.

Formation.—Carboniferous Limestone.

Localities.—Little Island, Cork; and Trearne, Beith, Ayrshire.

2.—CYCLUS RADIALIS, Phillips, sp. Pl. XV. Fig. 2. × 4 times natural size.

Agnostus radialis, Phillips, 1836. Geol. Yorks. vol. ii. t. xxii. fig. 25.
Cyclus radialis, H. Woodw. and J. W. Salter, 1865. Cat. and Chart Foss. Crustacea, p. 15, fig. 14.
Cyclus radialis, H. Woodw., 1868. Brit. Assoc. Rept. p. 75, pl. ii. fig. i.
Cyclus radialis, H. Woodw., 1870. GEOL. MAG. Vol. VII. Pl. XXIII. Figs. 2 and 2*a*, p. 557.

Dr. John Young, F.G.S., of the Hunterian Museum, Glasgow University, very kindly submitted the small specimen to me, which is drawn (Pl. XV. Fig. 2), as probably a new species; but, after comparing it, I am of opinion that it should be referred to Phillips's *Cyclus radialis*. The specimen, which is imperfect around the border, is from the Carboniferous Limestone of Beith, Ayrshire, and is attached to a portion of a frond of *Ptilopora* or *Fenestella*.

The carapace measures 6 millimètres long, by 5 mm. broad. As it is less perfect than the type it is needless to give a fresh description of it here.

Formation.—Carboniferous Limestone.

Localities.—Little Island, Cork; Bolland and Settle, Yorkshire; Trearne, Beith, Ayrshire; Visé, Belgium.

3.—CYCLUS SCOTTI, H. Woodw. Pl. XV. Fig. 3. × twice nat. size.

Cyclus Scotti, H. Woodw., 1893. GEOL. MAG. Dec. III. Vol. X. p. 28 (Woodcuts A, B).

Notwithstanding the difference in the size between Mr. Scott's specimen from the Coal-measures of Bacup and Fig. 3, from Mr.

Henry Johnson's collection from Coseley, near Dudley, I am inclined to refer them both to the same species.

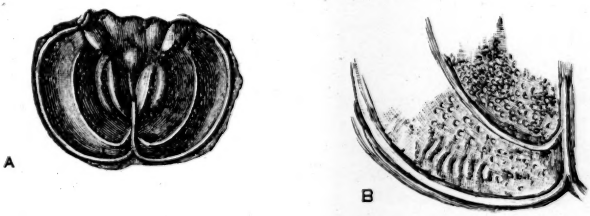


Fig. 3.—*Cyclus Scotti*, H. Woodw., Lower Coal-measures, Bacup, Lancashire.
A. Dorsal aspect of carapace (nat. size).
B. A portion of the left posterior border, magnified to show ornamentation.
[See Geol. Mag. 1893, Dec. III. Vol. X. p. 28, for full description.]
Length of Bacup specimen 20 millimètres long and 25 mm. broad.
,, of Coseley ,, 10 millimètres ,, and 13 mm. ,,

The most striking feature about this specimen is the very strongly accentuated raised circular lines which give quite a character to this form, and also the very steep acclivity to the outer margin of the shield, save at the anterior border, which is marked by indistinctly preserved oval prominences.

As this species was so recently described (1893) in this Magazine, it may be sufficient to point out that in our Plate XV. Fig. 3 the anterior border does not show the two inner oval prominences noticeable in *C. Scotti* (see Woodcut above), and which are very distinctly marked in *Cyclus* (*Halicyne*) *agnotus*, H. von Meyer, sp., from the Muschelkalk of Rottweil, Germany (see Geol. Mag. 1870, Vol. VII. Pl. XXIII. Fig. 8), a form that, in some respects, comes near to our Coseley *Cyclus*. The ornamentation on the surface of the carapace has a similar finely granulated appearance in both specimens, and the encircling ridges in both are very strongly marked.

Formation.—Pennystone Ironstone of the Coal-measures.

Localities.—Coseley, near Dudley, Staffordshire, and Bacup, Lancashire.

4. Cyclus Johnsoni, H. Woodw., sp. nov. Pl. XV. Figs. 4, 5, 6, 7.

I have ventured to place the four examples (Figs. 4–7) and some others not figured, all from the "Pennystone" ironstone of the Coal-measures, Coseley, near Dudley, in one species. Fig. 4 exposes the outer dorsal surface: Figs. 5, 6, 7 (which, like the preceding Fig. 4, are all drawn twice the natural size) show the dorsal shield more or less removed, especially over the central part, revealing the fact of the similarity of all three species *on the underside* to *C. Rankini* (Pl. XV. Fig. 8). The following are the measurements of the four figured examples:—

Fig. 4.	Length,	14	mm.	... ...	Breadth,	16	mm.
Fig. 5.	,,	14	,,	... ...	,,	18	,,
Fig. 6.	,,	12	,,	... ...	,,	16	,,
Fig. 7.	,,	13	,,	... ...	,,	15	,,

Spec. char.—Carapace rounded, width somewhat greater than length, broader and flatter in front, narrower behind, and with a shallow rounded indentation at the centre; having a broad and well-marked flattened rim, followed by a corresponding shallow depression around the lateral and posterior borders; front border tumid, with two (or more?) raised rounded or ovoid prominences; carapace with a median dorsal ridge reaching from the posterior border rather more than half way up the centre of the shield, then bifurcating so as to embrace a triangular space, which widens out to the anterior border; carapace with moderately raised and roundly swelling side-lobes (not strongly ridged as in *C. Scotti*) and with a pair of smaller oblong faintly raised lobes next the median ridge.

Appendages.—These consist of a pair of rather stout antennæ (probably the second pair of antennæ), showing about four joints on each side, the rest having been broken off. These are seen on Figs. 4 and 5, and faintly on Fig. 6.

Eyes.—Fig. 7 shows traces of two small eyes occupying the same relative position as the one seen more distinctly in Fig. 8 (*C. Rankini*), and which appears to be pedunculated.

The under-surface of the animal is partly exposed in Figs. 5, 6, and 7 by the accidental removal of a part of the dorsal surface of the carapace which remained adhering to the other half of the clay-ironstone nodule when it was split open.

In each of these examples, the converging bases of 6–7 pairs of gnathopodites are seen uniting mesially behind the V-shaped oral area (already referred to on p. 533) the median ridge behind which may indicate the posterior prolongation of the straight alimentary canal.

In all these specimens, the bases of the limbs have a very close agreement with *C. Rankini* (Pl. XV. Fig. 8). In Fig. 5 there is a slight indication of the base of an appendage on the central posterior border, which may have been part of a tail-spine; but it has not been observed in the others. Wherever the surface is preserved there is a fine granular ornamentation observable, more especially in the hollow formed within the broad flattened rim that surrounds the greater part of the shield. Fig. 7 is distinctly *more rounded* in outline than the others, and may possibly belong to another species.

I have dedicated this form to the memory of the finder, the late Mr. Henry Johnson, F.G.S., to whose labours as a geologist in the Dudley area we are so largely indebted for our knowledge of the fossil fauna and flora both of the Coal-measures and the Wenlock Limestone.

I must not omit to record my thanks to my son, Mr. Martin Fountain Woodward, of the Biological Laboratory in the Royal College of Science, for much valuable aid in the examination of these minute specimens, and to my daughters for their excellent figures in illustration of this and so many other papers which have appeared in this Magazine.

EXPLANATION OF PLATE XV.

FIG. 1*a*, *b*. *Cyclus Jonesianus*, H. Woodw. (1870). × 3 times nat. size. Fig. 1*b*. Lateral view. Carboniferous L. Trearne, Beith, Ayrshire. Coll. Dr. John Young, F.G.S., Glasgow.

FIG. 2. *Cyclus radialis*, Phillips, sp. (1836). × 4 times nat. size. Dorsal view. Carb. L. Trearne, Beith, Ayrshire. Coll. Dr. John Young, F.G.S., Glasgow.

FIG. 3. *Cyclus Scotti*, H. Woodw. (1893). × twice nat. size. Dorsal view. Clay-ironstone nodule, Coal-measures, Coseley, near Dudley, Staffordshire.

FIGS. 4, 5, 6, 7. *Cyclus Johnsoni*, H. Woodw. (1894). × twice nat. size. In Pennystone-ironstone nodules, Coal-measures, Coseley, near Dudley.

FIG. 4. Dorsal view, showing (2) antenna on right side and surface of shield.

FIG. 5. Dorsal view, showing parts of a pair of antennæ (imperfect), and trace of tail-spine. Dorsal shield partly decorticated, showing converging bases of limbs and labrum?

FIG. 6. Dorsal view of shield, partly decorticated, showing under-surface and traces of bases of antennæ.

FIG. 7. Dorsal view, decorticated, showing bases of limbs and traces of small eyes (pedunculated?).

FIGS. 3–7 are from the late Mr. Henry Johnson's Collection, now in the Geological Department Collection of the British Museum (Nat. Hist.), Cromwell Road, London, S.W.

FIG. 8. *Cyclus Rankini*, H. Woodw. (1868). × three times nat. size. Dorsal aspect of shield showing 6–7 paired bases of limbs converging upon labrum; each limb giving rise to a biramous swimming or other appendage (see Woodcut in text, p. 534). A small eye (pedunculated?) is seen in front on the right side and traces of an antenna?; also impression for muscles of sucker-attachment? Coal-measures, Carluke, Lanarkshire. Hunterian Museum Coll. University of Glasgow.

II.—PHYSIOGRAPHICAL STUDIES IN LAKELAND.

By J. E. MARR, M.A., F.R.S., Sec.G.S.

2. SWINDALE.[1]

TO the west of the London and North-Western Railway, after it has surmounted the incline of Shap Fells, lies the valley of the River Lowther, which eventually flows into the Eamont, which in turn drains into the Eden. The Lowther, flowing in a general northerly direction, receives the drainage of three important streams, coming from the south-west. The first of these flows through the valley of Wet Sleddale, just north of the Fells, which exhibit the exposures of the Shap Granite. It is lettered W.S. in Fig. 1. The second, Swindale (S. Fig. 1), the subject of this paper, joins the Lowther stream at Rossgill Hamlet, about two miles north of Shap Village, whilst the third, Haweswater Beck (H.B. Fig. 1), flows out of Haweswater (H. Fig. 1) and joins the Lowther at Bampton.

Proceeding up Swindale from Rossgill, we follow the road over Rossgill Moor, a barren tract of country occupied by Skiddaw Slates, to Swindale Foot, near which the Borrowdale Volcanic Group appears, and causes the fine cliff scenery which marks the upper part of Swindale. The road proceeds at the foot of these cliffs to Swindale Head, a farm about four miles from Rossgill, and a little below the semicircular line of cliff, which has been a prominent

[1] For No. 1, "Church Beck, Coniston," see GEOL. MAG. November, p. 489.

object during our walk, and which here appears to close up the valley: of this more anon.

On the side of the stream, opposite Swindale Head Farm, a prominent cliff known as the Knott (K. Fig. 2) rises up from the valley; its top is well ice-worn, but the lower part of the cliff, protected from the ice flowing down the valley, is rough and angular. To the south of the farm we come across a fine moraine, which has once blocked the drainage and formed a lake, now converted into a marsh, called Dod Bottom. This moraine is here seen

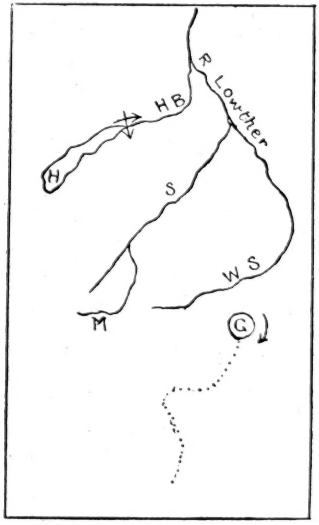


FIG. 1.

to have plastered the south side of the Knott (*i.e.* the side facing the direction from which the ice came), so that, but for the appearance of two ice-worn knobs of rock at the top, anyone coming down the valley might suppose that the Knott was entirely composed of moraine-matter. Just south of the Knott is a large boulder, known as the Simon Stone. So much for one of the prettiest exhibitions of glacial action to be found in the district; let us now return to the structure of the valley, apparently hemmed in by cliffs at its head. The great cliffs south of Swindale Head are reft down the middle by a narrow gulley (having the far from euphonious name of Hobgrumble Gill), down which a small stream pours from the hill known as Howes, of which these cliffs form the north face. The main stream, however, enters the valley from its east side, descending the cliffs in a series of waterfalls, which, notwithstanding the volume of water, have done very little work in the way of cutting a valley. This part of the stream is called "The Forces" (F. Fig. 2). Climbing to the top of it we enter a desolate part of the valley, up which we walk for about a mile in a southerly direction, after which it turns sharply to the left and proceeds for nearly two miles

towards the south-west to its head, at the pass separating it from Long Sleddale. This upper part of the valley is known as Mosedale. It is a very different valley from that of Swindale proper, being dreary in the extreme, and having its floor largely choked up with peat. The col separating it from Long Sleddale is 1661 feet above sea-level, that which divides it from Wet Sleddale about 1540 feet. An inspection of the map suggests at once that Mosedale may once have formed the upper part of Wet Sleddale (see Fig. 2), of which it is a direct continuation, whilst the course which the stream now takes to reach Swindale proper is decidedly remarkable.

If we walk up the Mosedale Valley, about as far as Mosedale Cottage, and look back at the col separating this valley from Wet Sleddale (F.C. Fig. 2), a remarkable appearance is seen: the col is

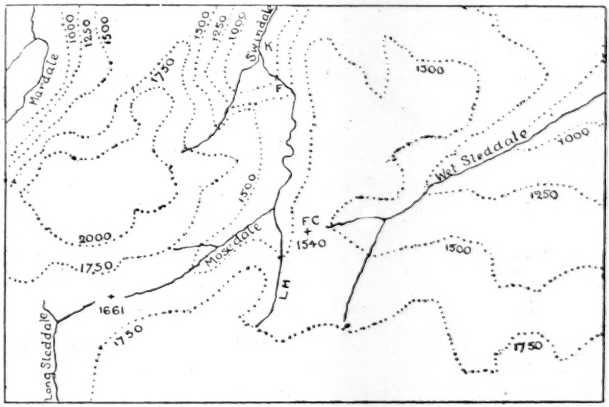


FIG. 2.

perfectly flat-topped for a considerable distance, like part of an alluvial plain. My colleague, Mr. Harker, remarked to me, when we were in this valley, "that is the most curious watershed I ever saw." As the appearance might have been deceptive, I visited the valley again this year, and made a close examination of this watershed. Reaching the summit, it is found to be perfectly level for some scores of yards across. It has a covering of four or five feet of peat, which rests on a clayey mass containing numerous stones. On the Mosedale side this superficial accumulation extends to within about thirty feet of Mosedale Beck, though it may actually fill a narrower channel much nearer to the level of the Beck. On the Wet Sleddale side the ground sinks gradually as a peat-covered slope for about half-a-mile, and the nature of the slope indicates that it is composed of drift beneath the peat. The point where rock first appears below this tract in the Wet Sleddale Valley is at a lower level than that part of Mosedale Beck adjoining the col.

It seems impossible to avoid the conclusion that the material underlying this flat-topped watershed was deposited by water,

though at first sight the difficulty of getting a sheet of water other than the sea at a point now forming the watershed between two valleys appears great. Furthermore, the distribution of the superficial deposits leads one to infer that if they were entirely removed, we should find the Mosedale Valley practically continuous with that of Wet Sleddale. How, then, is the nature of this col to be accounted for?

Its extreme flatness forbids the idea that it is a dry delta brought down during violent floods by the Little Mosedale stream (L.M. Fig. 2), which seems the easiest explanation. Moreover, the material beneath the peat is not of the character which we should expect on this supposition. The mixture of stones and very fine clay suggests deposit in still water, combined with the agency of ice, but the occurrence of a tract of still water in a position now occupied by a col between two valleys necessitates the existence of two barriers, one between Mosedale and Swindale proper, the other in Wet Sleddale below the peat-covered slope. If the Mosedale Valley were, as it appears to have been, at one time a continuation of Wet Sleddale, an ordinary barrier of rock (possibly somewhat rotten, as is often the case on the ridges of this district) would intervene between it and Swindale, but no such barrier can have existed lower down Wet Sleddale, and the only possible barrier in this direction which would produce the required effects is one of *ice*. A mass of ice crossing the Wet Sleddale Valley in its lower part would pond back the waters of the upper part of the valley (including what is now Mosedale) and convert it into a lake. The water of this lake would escape over the lowest point, which was probably situated in Mosedale a little below the present col between it and Wet Sleddale; this col must have been more than 1540 feet high (the height of the flat-topped col), and must have been less than 1661 feet (the height of that between Mosedale and Long Sleddale). The water thus switched off into Swindale would cut out the portion of the valley now running north and south between the alluvial col and the Forces. As the stream, at the point where the ridge between Mosedale and Swindale is supposed to have existed, is about 1300 feet high, an erosion of less than 200 feet is required, which could be readily performed during the period which has elapsed since the existence of the ice-dam. Granting the formation of this ice-dammed lake, we have all the requisites for the formation of the flat-topped watershed of superficial detritus. The fine clay would be derived from melting icebergs, as would also some of the stones with which it is mixed, whilst others would be brought into the lake by the Little Mosedale stream to form a subaqueous delta, which would eventually extend right across the lake and cut it in two, thus entirely separating what is now Mosedale from Wet Sleddale, and diverting its waters into Swindale. If the large volume of water which now runs over the Forces has been thus diverted in that direction, comparatively recently, this will account for the insignificant groove which those waters have cut out, whereas, if Mosedale had always been part of Swindale, it

would be difficult to account for this, and for the great difference in height between the upland Mosedale and the lowland Swindale Valley.

But how could a barrier of ice move across Wet Sleddale in a direction at right angles to the trend of the valley, which points towards the centre of the Lake District? Such a barrier must have originated either to the south (on the Shap Fells) or to the north. It can hardly have been from the south, for the highest point of Shap Fells is only 1852 feet above sea-level; that is, less than 300 feet above the top of the required ice-barrier, and less than two miles to the south of it. There are, however, further reasons for believing that the ice did not come from the south but from the north, and that the ice-barrier which blocked Wet Sleddale was the western part of the Scotch ice, which occupied the Eden Valley, and carried boulders of Criffel granite over Stainmoor, or ice from the north end of the Lake District pushed south by this Scotch ice. As the existence of this ice mass in the Shap area is a matter of some importance, I propose to consider the evidence for it in detail.

In the Fifth Appendix to the late Prof. Carvill Lewis' valuable "Glacial Geology of Great Britain and Ireland," Mr. Kendall refers to the transport of boulders of Shap granite over Stainmoor, and also to the north towards Penrith, and to the south *viâ* Hest Bank and Lancaster, and observes: "This remarkable distribution appears to me to point very clearly to the action of land-ice, and the dispersal in these directions may be accounted for partly by the fact that Shap Fell was the ice-shed (which is indicated by the striæ) as it is now the watershed; and, so far as its Yorkshire distribution is concerned, by the action of the land-ice from Criffel, which was driven up the Solway Frith and the Vale of Eden during the period of maximum glaciation by the congested state of the northern part of the Irish Sea." Agreeing, as I do, with most of Mr. Kendall's conclusions, he will perhaps forgive me if I differ from him on one point, namely, "that Shap Fell was the ice-shed." If this were the case, we should hardly find, as we do find, boulders of granite extending due east along the present line of watershed (occurring at a height of 1200 feet on Orton Scar). Moreover, a series of striæ curves round the east side of the Shap granite right across the watershed (see Goodchild, Q.J.G.S. vol. xxx. map opposite p. 98; also see arrow to east of Shap granite, G. Fig. 1). The direction of the southerly train of boulders from the Shap granite is described by Mr. Dakyns in the Proceedings of the Yorkshire Geological and Polytechnic Society for 1878, and more fully by Mr. Strahan in the Geological Survey Memoir relating to the country around Kendal, Sedbergh, Bowness, and Tebay (1888 edition). From the description given in this memoir the direction of the train of boulders south of the Shap granite represented by the dotted line in Fig. 1 is taken.

At the foot of Haweswater, I have observed *roches moutonnées* striated in two directions, a faint set running W.S.W.–E.N.E. (that is, in the general direction of the Haweswater Valley), crossed by

a more pronounced set running N.N.W.–S.S.E. (see arrow at foot of Haweswater, Fig. 1).

These various phenomena are best explained by supposing that the Lake District ice at first extended far to the eastward, producing the faint scratches at Haweswater, and the eastward distribution of Shap boulders over Stainmoor, and that as the Lake District ice shrank, the ice from the northward (either South Scottish ice, or ice from the northern part of the Lake District diverted southward by the Scotch ice) extended southward, curving round the high ground on the east side of the Lake District, forming the prominent striæ at the foot of Haweswater, *blocking up the Wet Sleddale Valley*, and carrying the southerly train of Shap boulders to Kendal and Lancaster. (The replacement of a mass of ice from the heart of the Lake District by one coming from the northward is also maintained by Mr. Dakyns, for different reasons, in the paper referred to above.)

But to return to the flat-topped watershed: Could it not have been formed during a period of submergence? If an arm of the sea extended up Wet Sleddale and Mosedale, might not the condition of things above described have been produced? The deposit no doubt might, but how is the Mosedale drainage to be deflected from Wet Sleddale to Swindale by this? However, the main objection is the local nature of the deposit; no sign of marine deposit is to be detected in the lowland valley of Swindale, which would be admirably adapted for receiving and preserving sea-sediment, nor do the neighbouring valleys give any proofs of an incursion of the sea, for I hold that the observations of Tiddeman, Goodchild, Dakyns, and Strahan have abundantly proved that the distribution of boulders in this district is not the result of marine action, but of land-ice. It is incumbent upon anyone who maintains that these boulders have been carried by floating ice, to account not only for the carrying of the Brockram blocks of the Eden Valley over Stainmoor, as described by Mr. Goodchild, but also the entire absence of Shap granite boulders in the Lune Gorge below Tebay, as described by Mr. Strahan.

To sum up:—1. The physiography of Mosedale suggests that it once formed part of Wet Sleddale and not, as now, of Swindale.

2. Mosedale is separated from Wet Sleddale by a flat-topped watershed, which gives evidence of having been formed by the deposition of superficial materials under water, and the distribution of this superficial material leads one to suppose that if it were removed we should find that Mosedale again formed practically a continuation of Wet Sleddale.

3. The presence of water other than the sea requires a dam across the Wet Sleddale Valley, below the point to which the superficial accumulation extends.

4. The only dam that can have existed here is a temporary one, such as would be formed by ice.

5. The distribution of the striæ and of the Shap granite boulders, points to a mass of ice coming from the north down the low ground on

the west side of the Eden valley, and abutting against the high ground of the east side of the Lake District. This ice would (according to the striæ and the distribution of the boulders) have taken the exact direction required in order to form the temporary dam.

6. Unless the above explanations be proved erroneous, it is unphilosophical to advocate a great submergence to account for the phenomena, a submergence to which other phenomena seen in the neighbourhood are in direct opposition.

III.—Notes on the Geology of Western Australia.

By Harry P. Woodward, F.G.S., F.R.G.S., Government Geologist, Perth.

As Western Australia is attracting considerable notice on account of the recent rich gold discoveries, a short paper upon its geological formations may be of interest.

Regarded as a whole, Western Australia is not an interesting field for geological research, at any rate from a stratigraphical or palæontological point of view, for, with the exception of one or two districts in the north, all the rock-outcrops are either granites, crystalline schists, or volcanic dykes.

Physical Features.

Although surrounded on three sides by the ocean, the coast-line is comparatively short, being only about 3,500 miles to the superficial area of 976,000 square miles. It is low and uninteresting on the whole, being destitute of bold headlands; the shore is either flat and little above the sea-level, or when cliffs do occur, they rarely exceed an elevation of 100 feet. These cliffs appear mostly where the escarpment of the table-land, which extends into the interior, has been cut off abruptly by the sea. That the coast has been elevated in recent times is proved by numerous raised beaches—low shelly limestone-cliffs, containing remains of existing species of mollusca, etc., and by large deposits of dead marine shells in the estuaries of the rivers upon the south-west coast. Upon the southern portion of the coast there is very little rise and fall of tide, but to the northward of North-west Cape it is considerable (being 46 feet in King's Sound), the constant alteration of sea-level playing an important part as a denuding agent along the coast and inlets.

The interior is most accurately described as a low, gradually-rising table-land with no bold ranges, the highest hills in the colony not exceeding 4,000 feet above the sea-level. There are no navigable rivers, and with the exception of a few in the South-west (which are always running) they are only immense storm-water channels.

The so-called lakes of the interior are large salt-marshes or clay-flats, being, in fact, the upper courses of the rivers where there is but little rainfall, and the country is so level that the water spreads out over the flats, where, except in very wet seasons, it evaporates, leaving a deposit of mud and salt behind.

There are no active volcanoes, but large lava-flows exist, and extinct craters are said to have been met with.

Geological Features.[1]

In describing the geological features it will be necessary to divide the country into six sections: namely, the North, North-west, West, South-west, South, and Central.

The North or Kimberley section embraces all the country to the northward of Roebuck Bay and eastward to the northern territory of South Australia. It consists mostly of broken country and is very interesting geologically, as many good sections of the Palæozoic rocks are exposed in the river gorges. Near the coast the Upper Carboniferous series is largely developed, whilst the Devonian, Silurian, Cambrian, and Archæan rocks are met with further inland. Moreover, associated with these older rocks there occur rich deposits of gold at the heads of the Ord and Fitzroy rivers, whilst to the eastward, on the border of the colony, one of the largest known basaltic lava-flows is met with.

Along the North-west coast the country is also much broken, but here the crystalline and granitic rocks outcrop directly from the alluvium with occasional bold hills and ridges of trap-rock, and it is amongst these that the gold deposits of Pilbarra are found. Further to the southward there is a table-land composed partly of Dolomite and partly of Basalt, but these formations are of no great thickness as the clay slates are exposed in the Ashburton valley, where some important discoveries of gold have been made.

The Western section stretches south from North-west Cape to Champion Bay, and consists of low cliffs formed of later Tertiary strata. Inland, in the northern part, a sandy plain extends for some 20 or 30 miles, as far as a narrow ridge of Mesozoic hills running north and south, and is followed to the eastward by a belt of Lower Carboniferous rocks which immediately overlie the crystalline schists. South of the Murchison River, near Northampton and Geraldton, a fine series of Mesozoic rocks is exposed in the broken table-land near the coast. These formations rest unconformably upon the crystalline rocks, with their rich copper and lead-lodes.

The South-western coast consists of low-lying sand-plains of recent origin, with many salt estuaries, lakes, and swamps, which extend inland for a distance of from 10 to 20 miles. Rising abruptly upon the eastern side of these plains is the Darling Range, composed of crystalline rocks, which attain a general elevation of about 1000 feet above the sea-level. The surface of this range and the country for about 50 miles to the eastward of it, is mostly covered by deposits of indurated nodular ferruginous clay-stones called "ironstone gravel." This deposit is often of considerable thickness, and, particularly upon the high ridges, is often cemented together into blocks of conglomerate called "ironstone."

In the river flat of the Collie, on the east side of the range, about 30 miles from the coast, Coal-measures have lately been discovered, and a fine series of seams has been proved to exist by boring. Nevertheless, no outcrop of this formation is visible at the surface,

[1] See a Notice of Geological Map and recent publications on Western Australia, in Geol. Mag. September Number, pp. 420–425.

for the whole is covered by sand. From Cape Naturaliste to Cape Leeuwin is a low ridge of crystalline rocks, but between this and the Darling Range the low swampy and sandy flats still continue to the south coast. Beneath this flat a large series of Mesozoic Coal-seams have been discovered by boring, but no Coal of commercial value has yet been found.

The South coast consists of a series of rough granite headlands, with low sandy and swampy country behind them, and this extends inland for a distance of about 30 miles, when the crystalline rocks again outcrop. This type of country extends eastward as far as the Great Australian Bight, where a bold escarpment of limestone, about 200 feet in height, presents a vertical face to the sea, sometimes rising abruptly from it and sometimes being separated by low sandy plains and raised beaches.

The Central or interior section, as far as known, consists of a sandy table-land, broken by numerous lake basins, around which the granitic and crystalline rocks outcrop, and it is in these areas of depression that the rich gold-fields of Coolgardie, the Murchison, Yilgarn, and Dundas are situated. The sand-plains are supposed to belong to the Mesozoic age and to be the western extension of the "Great Desert Sandstone" formation of the Central and Eastern colonies.

It will be seen from the following summary that the principal geological formations are represented, although (if we except the Palæozoic formations) only to a small extent.

Cainozoic.

The *Recent* deposits are represented in the Lake-beds, River-Valleys, Estuaries, Sand-Dunes, Raised-Beaches, and Shell-Marls.

The *Pliocene* in the Pindan plains of Kimberley, ferruginous sandstones, and variegated clays, with plant-remains on the Gascoyne River and North-west coast; and the gravels and conglomerates of the Darling Range.

The *Eocene* in the Coralline limestones of Shark's Bay; clays, sandstones, grits, and conglomerates of Champion Bay; limestones with flints of the Bight.

Mesozoic.

The *Cretaceous* formation is met with near the coast, 50 miles north of Perth; it extends northward to the Murchison River, and occurs also in the Kennedy Range upon the Gascoyne River, and between Capes Naturaliste and Leeuwin. It consists of beds of chalky limestone, with flints, sandstones, conglomerates, and clays. The sandstone of the table-land in the interior is also supposed to be of this age.

The *Jurassic* formation underlies the Cretaceous in the Champion Bay district, where a series of Oolitic limestones, clays, sandstones, ferruginous sandstones, grits, and conglomerates occur, which contain the characteristic fossils.[1]

[1] See Geol. Mag. for Sept. and Oct. 1894, pp. 385 and 433, Pls. XII. and XIII.

Palæozoic.

The *Carboniferous* formation is largely developed in the Kimberley district, forming flat-topped hills and ranges which consist mostly of shale with quartzite cappings; there are also a few limestone beds. A small patch of the Upper Carboniferous formation has been discovered upon the Collie River, consisting of shales, sandstones, fireclays, with coal-seams. It is probably one of a series of small basins lying to the eastward of the range, but as the whole surface is covered by recent formations, this remains to be proved. The Lower Carboniferous outcrops upon the Irwin River, where there are a series of shales, fireclays, sandstones, and limestones, with coal-seams. This formation extends north in a narrow strip to the Lyons River.

The *Devonian* formation has only been certainly proved to exist in the Kimberley district, where there is an almost horizontally bedded series of sandstones, grits, conglomerates, shales, and limestones, which contain fossils; but on both sides of the Ashburton River there is a great extent of magnesian limestone, which probably also belongs to this age.

The *Silurian* rocks have only been identified in the Kimberley district, but they are probably represented in other parts of the colony by clay-slates and quartzites, as in the Stirling Range.

The *Cambrian* formation has also been proved to exist in the Kimberley district, where it contains the gold-bearing lodes.

Azoic, or Archæan.

The *Archæan* and *Crystalline* rocks are more largely developed in this colony than in any other portion of the world, outcropping as they do in all parts of the country, and, where they are overlain by more modern formations, these latter are rarely of any great thickness. This series is highly contorted, being folded into a number of parallel anticlinal and synclinal folds, striking north and south, and often presenting the appearance of a highly inclined dip, which is either nearly vertical, or trending slightly to the eastward. These rocks are much broken and faulted by numerous diorite and granite dykes; they contain many quartz-veins and iron lodes, and it is in this group of rocks that the principal auriferous deposits exist.

This great series of rocks may be subdivided into three sections, which, as a rule, run in parallel belts north and south, with a slight trend to the north-west in the northern part of the colony.

The first, or western, belt extends from the Murchison River to the south coast, but is very little exposed, except in the Northampton district, and a little south of the Irwin River, where it is rich in copper, lead, and zinc ores. It underlies the sandy coastal plains, outcropping here and there at the base of the Darling Range, forming a small range between the Capes Naturaliste and Leeuwin, and characterised throughout by lead, copper, and zinc lodes. The rocks of this belt are, for the most part, comparatively soft, consisting of clay-slates (often kaolinised), quartzites, and schists, with

dykes of diorite and granite, and veins of quartz and pyrites, containing lead, copper, zinc, iron, and ferruginous graphite.

The second belt extends northward from the south coast (forming the bold escarpment at the edge of the great plateau called the Darling Range) as far as the Murchison River. It then follows this river in a narrow belt in a north-easterly direction for about 200 miles, where it suddenly spreads out to the east and north-west from the Robinson Range to the Lyons River, disappearing beneath the magnesian limestones to the northward.

In this belt the rocks are mostly hard and crystalline, consisting principally of gneiss and schist, with dykes of diorite, granite, and felstone, and veins of quartz. The latter (as well as the diorite) often contains large quantities of pyrites, most of which yield a little gold. Tin is also being worked at the Green Bushes Tin-field, the ore being derived from the disintegration of quartz-porphyry dykes, in which it is associated with tourmaline and titanic iron. Besides iron and manganese, large deposits of kaolin of a very fine quality occur, as well as veins containing mica and asbestos; but these latter are too much weathered at their outcrop to be of any value.

Near Bridge town a very large deposit of graphite has lately been opened up: it exists in the form of a bed between talcose schists about 20 feet in thickness.

The third or great granite belt lies about 100 miles east from the west coast, and is about 100 miles in width, extending from the south coast to the Murchison River. It consists of a series of bold bare outcrops of gneiss or granite often 100 feet in height and covering several hundred acres in extent, rising from loamy flats. The rocks mostly outcrop in the depressions of the table-land, the higher portions of which are covered by sand-plains. This belt is absolutely destitute of mineral veins, and it is due to this barrier that the rich gold-fields to the eastward remained so long unprospected. These outcrops are made use of for the conservation of water in this dry portion of the colony, as they shed water like a house-roof, whilst around them there are many natural dams or basins filled with sand, which are either being cleaned out or wells are being sunk in them. The rocks of this belt consist entirely of gneiss and granite, much fissured and faulted, and traversed by numerous dykes of granite and diorite, whilst the main masses generally enclose fragments and masses of schistose and gneissic rock.

The fourth or first auriferous belt is situated immediately to the eastward of the granite belt, and is about 20 miles in width. It starts from the south coast at the Phillips River, extending northward in a narrow belt by the Ravensthorpe Range, Parker's Range, Southern Cross, Golden Valley, Mt. Jackson, Mt. Kenneth, Mt. Magnet, Austin's Lake to the Cue. Thence it takes a slight bend to the north-east to Nannine and the Star of the East, where it strikes more to the north, and skirting round the heads of the Murchison and Gascoyne Rivers, it turns north-west and follows down the Ashburton Valley to its junction with the Henry, finally dis-

appearing beneath the Palæozoic formation. The rocks of this belt consist mostly of hornblende, mica, or talc schists, of which the hornblende schist so closely resembles diorite that it is impossible to distinguish it in a broken specimen.

The rocks of this belt are a good deal broken and faulted by granite and diorite dykes and quartz lodes containing gold, iron, and copper. There are also some large magnesia lode-masses rich in fine gold, which will probably prove to be serpentine at a depth. Many of the lodes also contain large quantities of chlorite.

The fifth or second granite belt is about the same width, and similar in every way to the first mentioned. It extends from the south coast, following the line of the first auriferous belt north, and, like it, dipping under the Palæozoic table-land of the Fortescue. Only a small portion makes its appearance on the northern side on the Yule River near Pilbarra upon the north-west coast.

The sixth or second auriferous belt lies next, and at present its width is unknown, but it is certainly of considerable width in places, and has proved wherever prospected to be extremely rich in gold. It extends north from the Dundas Hills (where this formation first outcrops from below the sand-plains) by Wagemulla, Coolgardie, the Three Pinnacles, Ullaring, Lake Carey, and following about the same line as the other belts, and turning with them to the north-west by the Nullagine, Marble Bar, Pilbarra, Egina, and Mallina upon the north-west coast.

The rocks of this belt are generally very similar to those of the first auriferous belt, but the formation and lodes are a great deal more faulted and broken; however, to make up for this they are the richest that have ever been discovered.

The hornblende rocks of this colony are very remarkable in character, being met with most abundantly from north to south. They vary immensely in colour, structure, and external character, some at first glance having the appearance of clay-slate, but on being fractured they exhibit a structure similar to diorite, whilst others again only contain green crystals of hornblende disseminated through a quartz matrix or have a jade-like appearance, which latter variety are continually being mistaken for copper, nickel, or silver. With these rocks are associated the principal mineral deposits of the colony: gold, tin, copper, antimony, lead, zinc, manganese, and iron.

Igneous.

Volcanic.—No active volcanoes are known to exist in this colony, but as many volcanic (*Obsidian*) bombs have been discovered in the far north and in the interior, and large basaltic flows exist, extinct volcanic craters may occur, as has been stated. On the north-west coast, south of the Nullagine, and on the Fortescue River there are several lava-flows, but the largest development takes place in the Kimberley district, where a flow stretches from the east side of the head of the Ord River far into the northern territory of South Australia. At Bunbury, and one or two points on the coast around the south-west corner of the colony, columnar basalt occurs.

Plutonic.—Dykes of granite and diorite are found all over the colony. The surfaces of these rocks are often split up and weathered into rounded masses, having a water-worn appearance, owing to the angles and edges being first disintegrated, and then exfoliated, which eventually causes the mass to assume a rounded shape. Amygdaloids are met with in great variety in the north-west, where they form huge rugged hill masses, upon which nothing will grow. Both the matrix and the enclosures vary much in different places, the latter being most commonly agates and calcite.

IV.—On some Variolitic Rocks on Carrock Fell.

By Alfred Harker, F.G.S., Fellow of St. John's College, Cambridge.

THE district of Carrock Fell, in Cumberland, is one rich in varieties of intrusive igneous rocks. Those on Carrock Fell itself, while probably belonging to one period of igneous activity, fall under three or four heads, which can be arranged in chronological sequence, as follows:—

(i.) A large intrusion of gabbro generally laccolitic in character.

(ii.) A granophyre, also forming laccolitic bodies, but with associated dykes and veins which traverse the gabbro.

(iii.) A diabase or gabbro, not essentially different from the first intrusion, but injected later and under somewhat changed conditions.

(iv.) A large number of dykes and veins of intermediate to basic composition.

These last are found traversing all the other rocks, and therefore, if we are justified in grouping them all together, they represent the latest intrusions in the neighbourhood. They vary from straight dykes two or three feet wide to narrow and rather tortuous veins not more than an inch in width.

I have recently presented to the Geological Society an account of the larger intrusive masses of Carrock Fell,[1] and I originally intended to include also the minor dykes and veins alluded to. This purpose I abandoned in view of the multiplicity and variety of rocks which they include, but some of the specimens examined seem worthy of a brief notice.

The only account yet published of any of these minor intrusions is a description by Mr. T. T. Groom,[2] of a one-inch vein traversing the gabbro near the head of Furthergill Sike. This is a tachylite with some remarkable spherulitic structures, and is of distinctly basic composition, having 53·63 per cent. of silica and 20·00 of iron-oxides,[3] with a specific gravity of 2·99 (central zone 2·95). I have examined my friend's specimens, but have nothing to add to his description. Veins having a very similar appearance are numerous

[1] Part I., dealing with the gabbro, is published in Q.J.G.S. vol. l. (1894), pp. 311–336.

[2] Q.J.G.S., vol. xlv. (1889), pp. 298–304.

[3] Analysis by Mr. R. H. Adie (Groom, *l.c.*). The iron is estimated as ferric oxide, but is probably present in the ferrous state, which would explain the high total of 103·76 per cent.

about the summit of Carrick Fell. They have a dark compact appearance, with a colour varying from greenish-gray to brownish-gray. There is often a strong banding parallel to the walls of the vein, while a certain crumpling of the brittle rock has sometimes given rise to a kind of cross-jointing resembling a rough cleavage-structure.

A slice was prepared from one of these veins, about 50 yards east of the summit, the specific gravity of the rock being 2·846. The slice [1754] is considerably obscured by secondary changes. Where the structure is most regular, it shows dull round or ovoid spots, averaging 0·01 inch in diameter, set rather close together with clearer interspaces of a light brownish-green tint. This green substance might be taken at first glance for an altered glass; but when examined with polarised light it is seen to be doubly refracting, and the manner in which dark rays sweep across it, when the stage is rotated between crossed nicols, indicates a radiate arrangement of some birefringent mineral. In the thinnest parts of the slice it can be resolved into radiating bundles of very slender felspar-fibres, which seem to be impregnated and stained with chloritic matter. A common radiate arrangement extends over areas large enough to enclose several of the round spots mentioned, and is often sufficiently complete to give a rather imperfect black cross, but the areas which behave in this way interlock irregularly with one another. The round spots in some places seem to have a very obscure radial structure in themselves, giving sometimes a vague black cross, but in general they merely become darker and lighter when rotated, behaving with the adjacent interstitial matter, as if they shared in the larger radiate structure. In one part of the slide are little prisms, mostly untwinned, of oligoclase with a fluxional disposition.

Another rock examined comes from a four-inch vein a little west of the summit, and has a specific gravity of 2·806. In this [1755] the little round spots are wanting, and it is seen at a glance that the rock consists essentially of slender felspar-needles, about 0·03 inch long, grouped in sheaf-like bundles, which interlace with one another. A higher magnification shows that these little needles are themselves built up of very fine parallel fibres. As before, there are a few scattered felspars of larger size. The greenish material is here collected into definite patches, and may probably be taken to represent a destroyed pyroxenic mineral.

Specimens showing similar features come from the face of the cliff called the Scurth, at a spot about 450 yards W.S.W. of Stone Ends Farm. A slice from one of these [1552] shows very beautifully the sheaf-like grouping of the felspar-fibres which make up the great bulk of the rock. The central part of each sheaf is composed of parallel fibres, or may be compact enough to be regarded as a little felspar-crystal, but spreads out at its extremities into a fan-like bundle of fibres. Individual fibres give sensibly straight extinction, and in one or two little prisms sufficiently developed to show albite-lamellation, the largest extinction-angle measured from

the twin-line is 5°. These observations agree precisely with Michel Lévy's results for oligoclase of composition $Ab_3\ An_1$. The green mineral in this rock forms distinct slender rods and skeleton-crystals about 0·03 inch long, with occasionally a stouter crystal or pseudomorph. Most of it seems to be hornblende, but some is a feebly polarising chloritoid substance: possibly both represent an altered pyroxene. The specific gravity of this rock is 2·663.

Another specimen, richer in the green mineral [1757], gave 2·763, and yielded 59·8 per cent. of silica.[1] Oligoclase of composition $Ab_3\ An_1$ has a specific gravity 2·659 (Tschermak) or less (Goldschmidt), and contains 61·9 per cent. of silica: the higher density and lower acidity of our rock is sufficiently accounted for by the considerable quantity of a ferro-magnesian mineral which it contains. A similar mineral occurs more richly in a six-inch dyke traversing the gabbro of Iron Crags [1881], and this rock has a specific gravity of 2·906. Here, however, the little felspar-fibres have lost their radiate arrangement.

Readers familiar with British and foreign "variolites" will recognise in the preceding short descriptions features characteristic of those curious rocks, or perhaps more accurately features often found in intimate association with the more typical variolitic structures. But while such structures have usually been described in distinctly basic rocks, we have them here reproduced in rocks of intermediate chemical composition. Other veins and dykes in the neighbourhood are of thoroughly basic rocks, and if, as seems probable, the whole group had a common origin, we have here another problem in the differentiation of rock-magmas in this very interesting district.

V.—On the Application of the Sand-blast for the Development of Trilobites.

By H. M. Bernard, M.A., Cantab., F.L.S., F.Z.S.

MY endeavours to establish a genetic relationship between the Annelida and the Phyllopod Crustacean Apus[2] led me, very naturally, to the study of the Trilobites. Specimens were kindly lent me by Dr. Woodward, F.R.S., Prof. Judd, F.R.S., and by Prof. G. B. Howes, it being my privilege at the time to be working in the Huxley Research Laboratory, which is under his direction.

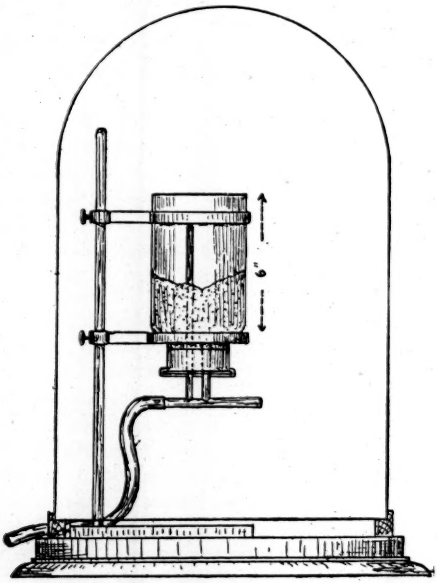
Picking at the fossil with a steel point taught me, what every worker soon finds out for himself, that the limbs which, under such a dorsal shield, would probably have been thin-walled structures, could not be differentiated from the matrix by any such method. Was there, then, no mechanical method of revealing the undersurface? At first I thought, among other things, of a stream of water, mixed with emery powder, forced through a rose; this idea

[1] This was kindly determined for me in the laboratory of the Yorkshire College of Science under the direction of Dr. J. B. Cohen.

[2] "The Apodidæ," Nature Series, 1892, and the Systematic Position of the Trilobites, Quart. Journ. Geol. Soc. August, 1894, Vol. L. pp. 411–432.

led, very naturally, to the sand-blast. A visit to the "London Sand-blast Works" (58A, Gray's Inn Road) gave some promise. The proprietor was kind enough to express interest in the idea, and showed me blocks of granite which had been treated with the sand-blast, and in which the harder elements stood out in good relief. A very short application of one of the sand-blasts belonging to the Works to the under-surface of a Trilobite from the soft Wenlock cleared away a large portion of the matrix, and revealed a small area of the under-surface of the carapace completely cleaned. In this specimen there was no trace of any under membrane having been cut through, and the carapace was probably the last remnant of a cast skin.

I then applied to Mr. W. I. Last, the keeper of the Machinery Division of the South Kensington Museum, for advice and assistance. He suggested several methods by which a constant stream of sand might be obtained, very kindly allowing me to make use of the air



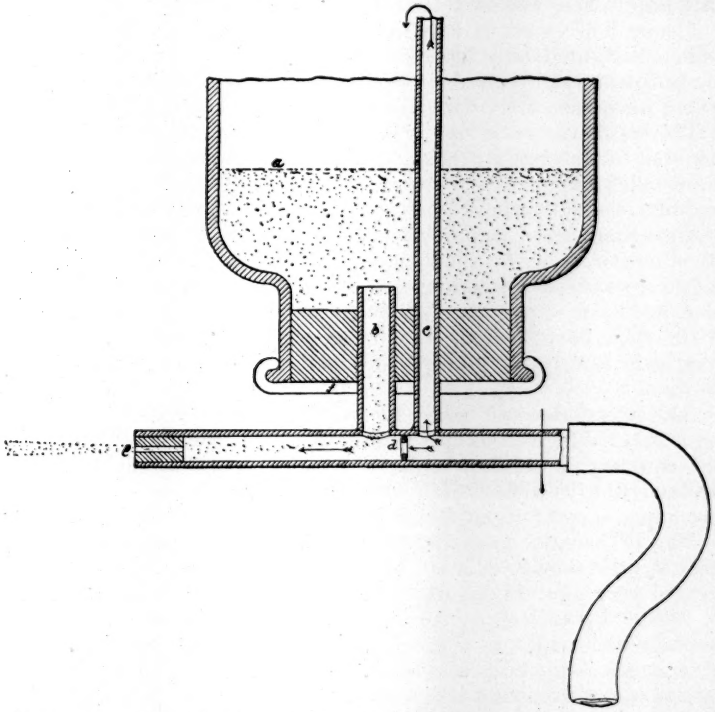
Reproduction of drawing (on greatly reduced scale) to show Sand-blast Apparatus for developing fossils, invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

pressure (about 5lbs to the square inch) by means of which the beautiful series of model engines in his charge are kept in motion or set working by the visitor on pressing a button. I take this opportunity of thanking Mr. Last very sincerely for the friendly assistance he rendered, for whatever is of value in this paper, viz. the description of the apparatus, is entirely due to him.

The sand was first thrown up from the bottom of a deep funnel by the air current rising in its base, always falling back again to

be again shot up. Under these circumstances it was not easy to manipulate the fossil, and the cutting action was not sufficient.

The sand was then allowed to run out through the funnel, which was connected by a short india-rubber tube with the nozzle of a blow-pipe apparatus. The air was forced through a small aperture just behind the feed, which, in this case, was sand instead of gas, and further, the aperture of the nozzle itself was narrowed by inserting a short piece of fine bore india-rubber tubing. The sand was shot out by this arrangement, with much greater velocity, but yet not with the highest possible, under the available pressure.



Enlarged section of part of Apparatus for developing fossils by means of the Sand-blast. Apparatus invented by W. I. Last, Esq. (Keeper of the Machinery Division), Science and Art Museum, South Kensington.

"The action, being partly due to induced currents, the amount of inert air carried along considerably reduced the velocity of the combined jet." Various other difficulties also had to be contended with—the dispersal of the sand, the clouds of fine dust, and, again, the manipulation of the fossil.

The final method planned and carried out by Mr. Last was the most ingenious: in order to get still more force, the sand was confined in a large bottle, but instead of being drawn into the air stream as before, it was forced in by the air pressure within the

bottle. This happy device brought the whole available force of the air upon the sand, and its cutting action was much increased. Mr. Last has kindly furnished me with a couple of sketches explaining the apparatus as it was used. In the section, *a* represents the level of the sand, nearly run out; *b*, the feed-pipe; *c*, the tube carrying the air above the sand; at *d* is a wire ring which, by contracting the air passage between the two vertical pipes, secures a slight excess of pressure within the bottle. Without this excess of pressure the sand was not fed into the jet in sufficient quantity; *e* is the nozzle, formed by a piece of fine bore india-rubber tubing; *f* is the wire clip to keep the cork from being blown out.

A considerably larger bottle might have been used with advantage. The one figured only lasted about five minutes; although it was easily filled, yet, when there was much matrix to be cut away, it would have been more convenient had it lasted 15 to 20 minutes.

The fossil was embedded in paraffin, for convenience of manipulation and for the ready protection of exposed parts, the under-surface alone being exposed. It was then fixed in position by screw clips in front of the nozzle of the sand-blast, and the whole covered with a large glass shade, to prevent the dispersal of the sand. The shade stood on feet so as to allow the air to escape. Parts which at any moment required protection were covered with the paraffin by means of a hot knife or needle. Various other methods of protection were tried, such as collodion, india-rubber solution (this applied by a fine brush), strips of gum-paper, small cardboard screens, but none of them helped much.

Although I devoted many hours to the process, I was too busy with other things to be able in any way to exhaust the method; on the contrary, I did but make a beginning, and cannot, therefore, pretend to give a final judgment on its merits. At the same time, my experience of it, as far as it went, may not be without interest.

The differential action is not so great as I expected it would be, still it undoubtedly exists. Many times structures appeared which looked very like fragments of limbs. These I did not care to try to save. I was looking for a series of segmentally arranged processes which ought to appear in more or less regular rows on each side, hence single fragments were of little use to me. The interesting question unfortunately remains to be solved: "Had such rows of limbs come into view, would the sand-blast have differentiated them, or would it have cut them away together with the matrix?" My experience, as far as it goes, makes me believe that this would depend entirely upon the hardness of the matrix. In one partly rolled specimen (such specimens, inasmuch as they must have been complete animals when they rolled up, are the most hopeful to experiment with), I found with a pocket lens, a regular row of dots close under the lateral edge of the head-shield. I worked away the matrix, commencing near the middle line and working slowly outwards towards these points so as if possible to reveal the limbs along their lengths. As I suspected, the points were the tips of structures which were almost certainly limbs, but the matrix was

so hard, that no differential action was possible, and further, the faint ridge of darker material which represented the limb first revealed was too thin to protect with paraffin.

On the other hand, if the matrix is not very hard, the sand-blast would almost certainly differentiate fine structures, provided, of course, they were not exposed too long to the action of the sand. My final plan, therefore, was to work away till I discovered by means of the sand-blast the existence of a serial row of limbs in a specimen, and then to blast away the matrix on all sides of these limbs, even through the dorsal surface, always stopping as soon as they showed as ridges, and then to work in some other way to clear the limbs further. Unfortunately, I never found such a specimen, and believe that it would be very difficult to find. The rolled-up or partly rolled-up specimens get filled with a substance too hard for the sand-blast to yield any result, while the limbs of the open specimens were probably flattened down against the dorsal carapace into a tangled mass. I did not, however, give up hope that, if I could work long enough at it and had sufficient material, the sand-blast would reveal something worth finding, if not a complete series of limbs. As above stated, many mysterious fragments and membranes appeared which kept me for a few days or hours in a state of tension. For instance, a fragment of the ventral membrane was very clearly shown in one specimen (figured in the paper above quoted).

The absence of nearly all tangible result from my own researches need deter no one from repeating the attempt. It must be remembered that a very large portion of the time I devoted to it was given to getting an apparatus which would work, and then when this was overcome by the mechanical skill and kindly assistance of my friend Mr. Last, other and more pressing duties called me away, so that on the whole I did not apply the method to more than six specimens in all. From every one of them I think I learned something, and I firmly believe that if anyone with more leisure and sufficient material would repeat the attempt, he would sooner or later certainly be rewarded. We have not by any means exhausted all that could be learned from a study of the inner surface of the dorsal shell, which the sand-blast is well able to clear out. In these cases, it is well to take care that the carapace is firmly bound together by strips of gum-paper, or by embedding in paraffin, otherwise it is very likely to fall to pieces as soon as the matrix is removed.

It may be said, in conclusion, that when the matrix is soft as compared with the fossil—and this would apply to all fossils—the sand-blast cleans the objects very beautifully, and for this alone, as an accessory method of investigation, it might be of great use to palæontologists. It is only with great regret that I have felt myself compelled, on account of other duties, to drop this method of investigation, and I hope that some one with sufficient leisure and opportunity will be tempted to carry it on.

NOTICES OF MEMOIRS.

Abstracts of Papers read before the British Association at Oxford, August 9–14, 1894.

I.—The Carboniferous Limestone, Triassic Sandstone, and Salt-bearing Marls of the North of the Isle of Man. By Professor Boyd-Dawkins, F.R.S.

THE Ordovician slates, quartzites, and conglomerates, and the associated volcanic rocks of the "massif" of the island gradually pass underneath the sand, shingle, and clay of the Boulder-clay series in going northward along the coast towards Kirk Michael, until they disappear altogether from the cliffs and the shore. They stand up conspicuously along the ancient shore-line extending from Kirk Michael to Ballaugh, Sulby, and Ramsey, commanding the low, sandy, and marshy region which forms the northern portion of the island, contrasting in its flatness with the lofty rolling Ordovician hills behind, culminating in Startfell, Snaefell, and North Barule. This contrast is obviously the result of a difference in the physical character of the rocks in the two districts. The problem as to which rocks underlie the glacial strata in the former, which had occupied the author's mind for many years, is now partially solved by the three borings which have been made under his advice by Messrs. Craine in 1891–94 in search of the Coal-measures of the Whitehaven field, at the Point of Ayre, at Blue Point, and at Shen Moar. The boring at Shen Moar revealed the existence of the Carboniferous Limestone at a depth of 167 feet 6 inches below the drift. The next bore-hole, at Blue Point, about 40,050 feet to the north-east of that at Shen Moar, revealed the presence of more than 60 feet of Red Sandstone buried 171 feet beneath the drift. The Red Sandstone in this section is, in his opinion, identical with the St. Bees sandstone, or lowest member of the Triassic formation in the district of the Lakes. This is greatly strengthened by the discovery in the third boring at the Point of Ayre, to the east of the lighthouse, of the Triassic marls with salt, at a distance of a little under five miles from Blue Point. The diamond drill was used from a depth of 452 feet to the bottom. The total thickness of the salt-beds amounts to 33 feet 6 inches, and the bore-hole happened also to intersect a brine run 2 feet 6 inches in depth. If this section be compared with that published by Mr. Dickenson of the saliferous marls of Duncrue, near Carrickfergus, it will be found to be practically identical. The same series of salt-bearing marls is also worked at Barrow-in-Furness and at Preesal, near Fleetwood. The salt-beds in each of these cases are variable in thickness, and those in the Isle of Man are thinner than in the other localities. It must, however, be remembered that the Manx boring has not been put down to a sufficient depth to test the true thickness of the salt-field. The discovery is of great theoretical importance, because it links on the deposit at Barrow with that of Carrickfergus, and shows the

Irish Sea was an area in which the salt-bearing Triassic marls were deposited. It points towards the truth of Mr. Dickenson's suggestion that the Cheshire salt-field was formerly continuous with that of Ireland. These marls have since been broken up, faulted, and denuded away in many places. It is an open question how far those of the Isle of Man are now continuous under the sea eastwards to Barrow and Fleetwood, and to the north-west in the direction of Carrickfergus.

All these rocks are buried under a great thickness of boulder sand, gravel, and clay, amounting at the Point of Ayre to 298 feet. To this also must be added the height of the drift hills close by, formed of the same materials, which would give the total thickness as not less than 450 feet in the extreme north. The rocky floor on which it rests dips rapidly to the north-east towards the deeper part of the Irish Sea.

The discovery of this salt-field is likely to add a new industry to the resources of the Isle of Man.

II.—Fossil Phyllopoda of the Palæozoic Rocks. Eleventh Report of the Committee, consisting of Professor T. Wiltshire (Chairman), Dr. H. Woodward, and Professor T. Rupert Jones (Secretary). Drawn up by Professor T. Rupert Jones, F.R.S., F.G.S.

1. A NEW species of Beecher's phyllocaridal genus *Elymocaris*, from the collection of Dr. G. J. Hinde, F.G.S., has been figured and described in the Geological Magazine for July, 1894, p. 292, Pl. IX. Fig. 7. It was found at Arkona, Ontario, Canada, in the Hamilton group of the Middle Devonian series.

Its nearest known ally is *Elymocaris capsella* (Hall and Clarke), from the Hamilton group of New York State, Palæont. New York, vol. vii. 1888, p. 181, pl. xxxi. fig. 4. It differs, however, in details of outline, ornament, and ocular spot. The new species is named *E. Hindei*, after its discoverer.

2. Two imperfect sets of abdominal segments, impressed on a piece of Moffat Shale (from Garpel Linn), have been noticed in association with a carapace of *Discinocaris Browniana*, and therefore probably belonging to individuals of either that genus and species, or of *Aptychopsis*, or possibly *Peltocaris*, which also occur in the Moffat Shales. The two above-mentioned specimens are figured and described in the Geological Magazine for July, 1894, p. 291, Pl. IX. Figs. 4*a*, 4*b*. Fig 3 shows the associated carapace. They belong to the Carlisle Museum.

We have noticed similar abdominal segments, but differing somewhat in size, associated with *Hymenocaris* in the Tremadoc slates, and with *Ceratiocaris* in the Upper Silurian beds. As such body-rings belong to various groups of these low-class Crustacea, it is not extraordinary that the above-mentioned genera should each possess the same kind of structure in the abdominal region.

3. A good-sized *Discinocaris Browniana* and the moiety of a rather large *Aptychopsis Wilsoni*, preserved in the Carlisle Museum,

have also been described and figured in the GEOLOGICAL MAGAZINE for July, 1894, p. 292, Pl. IX. Figs. 5 and 6. They are typical of the Moffat Shales.

4. It may be remarked that the figured interior of the bipartite carapace of *Macrocaris Gorbyi*, Miller, referred to in our Tenth Report, at page 468, Report British Association for 1893, appears (if looked at upside down) very much to resemble some of the bivalved *Aptychopses* figured in the Monograph of Palæozoic Phyllopoda, Pal. Soc., 1892, pl. xv., but with a more acutely sagittate outline, and without the definitely concentric umbonal striæ.

If the carapace in the drawing (fig. 43) exposes its *interior*, it seems to lie unconformably with respect to the body-rings, for they appear to be covered by the carapace upside down. If it normally covered the body it would show its *exterior*.

Is it possible that after death, the attachments of the body and carapace having been loosened, the carapace turned quite over, and the parts of the animal floated into a position reverse to what they held in life? Or have we here two valves and an imperfect body of an *Aptychopsis* which during decay were washed into a *reversed* position—that is, with the abdomen projecting from the anterior region, as is not unusual with some fossil *Ceratiocaridæ*?

5. By favour of Dr. Wheelton Hind, F.G.S., we have very lately seen, from Mr. George Wild's collection, some pyritous specimens of what seems to be a very small *Estheria* in shale from the roof of the Bullion Coal, Lower Coal-measures, lately worked at Trawden, near Colne, in North-east Lancashire.

6. A specimen of *Estheria Dawsoni*, Jones (GEOL. MAG., 1870, p. 220, Pl. IX. Fig. 15; *ibid.*, 1876, p. 576; *ibid.*, 1878, p. 101, Pl. III. Fig. 2), has been obtained from the vicinity of Five-Islands, Nova Scotia, by Mr. H. Fletcher, of the Geological Survey of Canada. Like a former specimen it may be from the Horton series; and has been sent by Sir W. Dawson, F.R.S., of Montreal, for our examination.

III.—ON THE PERMIAN STRATA OF THE NORTH OF THE ISLE OF MAN.

By Professor BOYD-DAWKINS, F.R.S.

THE main features of the geology of the island are identical with those of Cumberland and Westmoreland. The Ordovician strata form the "massif" in both areas, and constitute the sea-worn floor upon which the Carboniferous rocks rest unconformably. The Red Sandstone series of Peel, 1368 feet in thickness, occupies but a very limited area, extending from the Creg Malin, along the sea-front, in a line of picturesque cliffs, about one and a half mile to the north-east, and extending inland about 1700 feet. The rocks may be divided into two distinct groups. First, the Peel Sandstone series, or Roth-todt-liegende, which presents a thickness of 913 feet, and the calcareous conglomerates and breccias of the Stack series, 455 feet thick, representing the Magnesian limestone of the Permians. These rocks are faulted into the Ordovician slates, and neither their

true base nor their upper boundary is visible. The pebbles of Carboniferous Limestone in the conglomerates point to a post-Carboniferous age, and the physical characters of both divisions are identical with those of the Permian rocks of the North of England, and more particularly with those of the Lake District, of the Vale of Eden and Barrow Mouth, described by Sedgwick, Harkness, Binney, Eccles, and Nicholson. It is clear that north-eastern Ireland, the northern part of the Isle of Man, and the area of the Lake District, including the Vale of Eden, were parts of the same Permian marine basin, in which, as it approached southern Lancashire, the waters gradually were more highly charged with mud, the calcareous element being conspicuous in the one, and being replaced in the other by thick accumulations of marl.

REVIEWS.

I.—Nanno, a new Cephalopodan type. By J. M. Clarke. (The American Geologist, vol. xiv. pp. 205–208, pl. vi. October, 1894.)

THE author's description of this Cephalopodan type is based upon "seven specimens obtained from the Trenton shales of Minneapolis and from the Galena shales at Chatfield, Minnesota." All the specimens represent only one species, for which the name *Nanno aulema* is proposed. The species has the appearance of a short, stout, fusiform *Endoceras*, tapering rather rapidly to a somewhat acute point. The siphuncular tube (sipho) is marginal, and occupies nearly one-half of the diameter of the shell. "The septa are gently and regularly concave over most of their surface, but abruptly deflected immediately above the sipho." The conical posterior portion is aseptate; it is formed by the inflation of the siphuncular tube, which is covered by a thin layer of the test. As in the genus *Endoceras*, the siphuncular tubes (siphones) are sometimes found detached from the rest of the shell; they have then the appearance of small *Belemnites*, whose posterior extremity is somewhat inflated; the cylindrical portion bears oblique impressions as in *Endoceras*, but these are interrupted on that side of the tube which was in contact with the shell-wall. The siphuncular tubes are "completely solid in the apical portion for usually about one-half the length of the præseptal cone, but in some examples the solidification extends for the entire length of the cone and into the cylindrical part of the tube. The cavity of the sipho above this filling is a narrowly conical chamber, whose walls gradually become thinner from the apex upward, their upper edge appearing to be rounded off and finished."

"The substance of the siphonal cone and walls is invariably very compact, radially crystalline calcite." "Cross-sections of the cone in both directions indicate ✿ ✿ that this is composed of at least two invaginated and consolidated sheaths," similar to those found in *Piloceras*, *Vaginoceras*, and *Endoceras*, but the author did not observe any traces of a tube connecting the apices of these sheaths, such as has been described in *Piloceras* and *Endoceras*.

"All the specimens indicate that the shells were of small size. . . . . The most complete example has a length of 58 mm.; the apical cone measures 15 mm.; the entire diameter of the shell is 18 mm. at its widest part and 16 mm. at or near the aperture."

The author regards this Cephalopodan type as most nearly related to the genus *Piloceras*, but the figures accompanying the paper so closely resemble those illustrating Dr. Gerhard Holm's paper, "Ueber die Anfangskammer von *Endoceras belemnitiforme*" (Pal. Abhandl., Dames and Kayser, vol. iii. (1), 1885, pl. i.), that it would have been interesting if the author had pointed out the characters by which his "new Cephalopodan type" differs generically from Holm's *Endoceras belemnitiforme*. We think the two species are certainly referable to the same genus, and if Holm's species be a true *Endoceras*, *Nanno* becomes a synonym. It is, however, interesting to find that a structure very similar to that described by Holm has now been observed in American specimens. G. C. Crick.

II.—The Mammalia of the Deep-River Beds. By W. B. Scott. (Trans. Amer. Phil. Soc., Vol. XVII., pp. 55–185, Plates 1–6. Philadelphia, 1894.)

In this paper the author describes in detail a collection of Mammalian remains from the Deep-River Beds of Montana, a series of deposits occurring in a Tertiary lake basin, originally discovered by Grinnell and Dall in 1875. The beds consist of an upper and a lower division, from both of which collections have been made. The upper division is considered to form the lowest horizon of the Loup Fork Beds, which are referred by the author to the Upper Miocene. The lower portion is regarded as being on the horizon of the uppermost John Day. The former is tentatively correlated with the Miocene of Steinheim and Sansan, the latter with that of St. Gerand-le-Puy, while the White-River Beds are considered to be approximately equivalent to the deposits of Ronzon, and should therefore be referred to the Oligocene.

One of the most interesting forms from the lower division is *Cynodesmus thoöides*, a dog-like animal, represented in the collection by a beautifully preserved skull, the upper portion of which is broken away, exposing a natural cast of the brain case. The surface of the cerebral hemispheres is much less convoluted than in any recent member of the Canidæ, and the cerebellum is only very slightly overlapped by the hemispheres. The author considers that this animal is probably on the direct line of descent of *Canis*, connecting the latter with *Daphænus* of the White-River Beds, hence it is possible that the Canidæ must be added to the list of families that originated in the New World.

Of the Equidæ, *Desmathippus*, a most important form connecting *Miohippus* with *Protohippus*, is fully described. The teeth are low-crowned, with the valleys partly filled with cement, and, in the feet, the lateral digits are fairly well developed.

Of the genus *Anchitherium* (in the restricted sense employed by the author, *i.e.* excluding *Miohippus* and *Mesohippus*), one species,

A. equinum, occurs. This form fairly closely resembles the European species, *A. aurelianense*, but in some respects is of a more modernised type. The affinities of the genus are discussed at length and cogent reasons given for considering that it is quite off the direct line of descent of *Equus*, being probably an abortive side branch derived from *Miohippus*, or some allied form. If this be true the European representatives of the genus must have reached the Old World by migration.

The Rhinoceridæ are represented in the lower beds by some undeterminable fragments only, but in the upper the remains of a species of *Aphelops* are found. The author points out an interesting series of parallelisms in development between the hornless Rhinoceroses of America and their horned congeners of the Old World; the common ancestors of the two groups are probably to be found among the Aceratheria of the Oligocene.

Of the Artiodactyla, several species of Oreodonts referred to the genera *Mesoreodon*, *Merychyus*, *Merycochoerus*, and *Cyclopidius*, are described. *Mesoreodon chelonyx* is peculiar from the fact that it possesses an ossified thyroid cartilage, a character unique among mammals. It is suggested that this structure, like the greatly expanded basihyal in the howling Monkeys, was connected with great power of voice. The same species is further remarkable for the presence of a small ossified clavicle and of a distinct metacromial process on the scapula.

A small species of *Blastomeryx*, *B. antelopinus*, is described and its affinities considered. It appears to be an Old World type, nearly related to *Palæomeryx*, and may possibly be an ancestral form of *Antilocapra*, the American Prong-horn Antelope, which it must have closely resembled in outward form, the horns, however, being unbranched.

The Camelidæ are represented in the lower beds by *Poëbrotherium*, and in the upper by *Protolabis* and *Procamelus*. In the axis vertebra of *Protolabis* the odontoid process is intermediate in structure between the peg-like form occurring in *Poëbrotherium* and the spout-like condition found in *Procamelus* and the recent Camels, this latter form having been acquired among the Camels by precisely the same series of modifications as in the Equidæ, in which series *Miohippus*, in this respect, represents *Protolabis*.

Finally, in the upper beds remains of a Mastodon, *M. proavus*, Cope, are found; this is the earliest occurrence of the genus in America.

REPORTS AND PROCEEDINGS.

Geological Society of London.

November 7th, 1894.—Dr. Henry Woodward, F.R.S., President, in the Chair.

Sir John Lubbock exhibited specimens of fossiliferous limestone from the valley of Lauterbrunnen, at Mürren. He pointed out that the specimens contain *Nummulites Ramondi*, *Orbitoides dispansus*, etc.

as determined by Prof. T. Rupert Jones. The find was perhaps the more interesting because the specimens were obtained from a quarry by the road-side in the village of Mürren, and actually between the two principal hotels.

Mr. Etheridge referred to the position of the Orbitoidal limestones on the slope of the Mürrenberg, and stated that Prof. Rupert Jones had examined and named the Foraminifera, etc., contained in the several specimens collected by Sir John Lubbock and himself at Mürren.

The following communications were read:—

1. "Notes on some recent sections in the Malvern Hills." By Prof. A. H. Green, M.A., F.R.S., F.G.S.

The sections described occur on the east side of the Herefordshire Beacon, and for convenience are named the Warren House Rocks. They are bedded, and have a general north-and-south strike. The great bulk of the rocks are hard, close-grained, and splintery, and are largely altered, and in many cases thickly veined with calcite. Details of their structure are given; and the author states that he is inclined to regard them as a group of bedded acid lavas and tuffs, crossed by three bands of dolerite. What little balance of evidence there is seems to be in favour of the intrusive character of the dolerites. No true limestones have been found, and the only very calcareous rock seen is regarded as a rock belonging to the volcanic group which has been largely calcified.

Somewhat similar rocks are found on the southern part of Ragged-stone Hill, and a shattered felstone occurs forming an isolated boss south of Chase End Hill.

Several hypotheses present themselves as to the relationship between the Warren House Rocks and the crystalline schists. The former may be distinct from the latter, in which case the absence of mechanical deformation would indicate that they are younger. If we consider that the Malvern Schists have been formed out of volcanic rocks by dynamic metamorphism, the Ragged-stone Hill Rocks may be a portion of the volcanic complex which has undergone only partial transformation, whilst the Warren House Rocks have altogether escaped metamorphism, the crystalline schists representing its final stages.

2. "The Denbighshire Series of South Denbighshire." By Philip Lake, Esq., M.A., F.G.S.

The area to which this paper chiefly refers is the south-western quarter of the Llangollen basin of Silurian rocks. The beds are here very little disturbed, and the sequence is readily made out. The following subdivisions are recognized (in descending order):—

Leintwardinensis Slates; with *Monograptus Leintwardinensis.*
Upper gritty beds; with no fossils known.
Nantglyn Flags; with *M. colonus, Cardiola,* etc.
Moel Ferna Slates; with *M. priodon, M. Flemingii.*
Pen-y-glog Grit.
Pen-y-glog Slate; with *M. personatus, M. priodon, Retiolites Geinitzianus,* etc.

Farther east the fossiliferous beds of Dinas Brân appear to lie considerably above the *Leintwardinensis* Slates.

On comparison with other areas it is found that this succession is almost identical with that in the Long Mountain, in North Denbighshire, and in the Lake District. It is also inferred that the *Leintwardinensis* Slates represent the Leintwardine Flags of Herefordshire, and that the Dinas Brân beds correspond with a part of the Upper Ludlow.

3. "On some Points in the Geology of the Harlech Area." By the Rev. J. F. Blake, M.A., F.G.S.

In testing the conclusions arrived at in regard to the Llanberis and Penrhyn area by an examination of that of Harlech, two questions are raised concerning the latter:—(1) Can a succession be traced below the Purple Slates similar to that which the author has described as occurring in Caernarvonshire? and (2) Where is the most natural break in the series, and does it show an unconformity?

With reference to the first question, the author gives his reasons for concluding that, as far as the succession is seen in the Harlech area, it is similar to that of Caernarvonshire. A group of Purple Slates is described which so closely resemble the Llanberis and Penrhyn Slates, that he considers that he is justified in definitely correlating them with those slates. Below these are slaty greywackes, which, if not identical with those of Caernarvonshire, bear a greater resemblance to them than any other part of the series does. No older beds are seen. Above the Purple Slates are the Harlech Grits proper.

In discussing the second question, the author describes conglomeratic beds occurring some distance above the base of these Harlech Grits; but at Pont Llyn-y-Crom the junction between them and the underlying Purple Slates shows features recalling what is seen at Bronllwyd. He discusses the possible existence of an unconformity at the base of these grits, and concludes that on the whole the phenomena point, though not very strongly, to an unconformity of no great importance.

The concluding part of the paper is occupied with a consideration of the question of classification of the Cambrian strata and those in juxtaposition with them.

CORRESPONDENCE.

SIR H. HOWORTH ON THE HOLDERNESS BOULDERS.

Sir,—The title and some of the paragraphs of Sir Henry Howorth's latest contribution have been penned under a singular misapprehension. I have written not a word "on the Scandinavian Ice-sheet," nor offered any opinion as to the mode of transport of those very damaging boulders. I have, indeed, my own views on these questions, but have kept them to myself with the modesty which your correspondent recommends. This reserve I propose to maintain, despite Sir Henry's somewhat inconsistent challenge

to me to enter the lists against "the best men" among Glacial geologists—meaning, as he rather quaintly explains, the men he quotes.

The sole statement of mine with which we are concerned is that certain boulders extracted by Mr. Lamplugh and myself from the Holderness Boulder-clays are of Norwegian origin. Extricating from Sir Henry's communication what is germane to this question, I note first that the ballast theory has taken a more definite shape. It may have occurred to the writer that there is no port on the Holderness coast, and that the number of vessels from Christiania cast away there is limited. For whatever reason, Sir Henry now carries us back to the age of the Vikings, who, it appears, ballasted their ships with little pieces of rhombenporphyr, and used small pebbles of laurvikite for anchors; and he, apparently, would have us believe that the stones now on the strand have lain there undisturbed for many centuries! To anyone who has watched the movement of this beach, which no artificial works have been able to hold, or who reflects that in the days of the Vikings the Holderness coast-line must certainly have been several miles to seaward of its present site, this idea will come with all the force of novelty.

But, besides the pirates from Viken, Sir Henry has two other strings to his bow. One is the idea that we have mistaken boulders driven into the face of the cliff by high tides for boulders belonging to the clay. Sir Henry is rather fertile in suggesting foolish blunders that somebody else may have made, and I do not see how he is to be convinced on this point except by personally examining the cliffs that he writes about, which is perhaps too much to expect from so busy an author. But, since he inquires whether boulders of the rocks in question have been found inland, I venture to remind him of such a find made at Cambridge by an observer in whose caution he has, I am sure, full confidence. It was recorded by me in your July Number, and still awaits Sir Henry's attention. In the northern counties, where so many thousands of boulders have been critically examined, there is no record of the types in question except from the eastern coast-line.

This last significant fact will afford exercise for Sir Henry's ingenuity with reference to his remaining alternative, viz. that these rock-types may occur *in situ* somewhere in Britain, apparently in Durham, the Cheviots, or the Lake District. Assuredly this suggestion cannot have been submitted to the writer's petrological adviser. Recalling that the disputed boulders, of at least four distinct types, have all been matched in one district of Norway, and that the British areas indicated, which are as thoroughly known as any part of this country, have yielded nothing remotely resembling any one of those types, we may fairly ask for some surer ground for this very original hypothesis than the exigencies of Sir Henry Howorth's glacial theories.

St. John's College, Cambridge.
August 18*th*, 1894.

Alfred Harker.

NEW LOCALITIES FOR THE MINERALS *BROOKITE*, *NATROLITE*, AND *BARYTES*.

Sir,—I have recently discovered a new locality for *Brookite* and *Natrolite* in Caernarvonshire (the old locality is near Tremadoc). The Gimblet rock, Pwllheli, consists of a compact ophitic dolerite containing labradorite, large brilliant crystals of augite, and magnetite. Fissures traverse the rock in all directions, and are filled with quartz and calcite. Small bright crystals of *Brookite* are imbedded in the dolerite and project into the fissures; they are in many cases surrounded and covered by calcite, but are revealed on removal of the latter by hydrochloric acid. The largest crystals have a diameter of one quarter of an inch, and are tabular in habit: the large faces are striated in the direction of the vertical axis.

The mineral *Natrolite* occurs in geode-like cavities in the dolerite, and is intimately associated with calcite and quartz. The radiating spherical groups of *Natrolite* are white in colour, and from one quarter to half an inch in diameter.

Last August I had occasion to visit Dosthill, near Tamworth, and am able to add a new mineral to the list of those hitherto known as occurring in Warwickshire. The mineral is *Barytes*, and occurs in veins an inch in diameter in the Cambrian shales. The crystals have a beautiful reddish colour due to enclosed ferric oxide.

122, Linwood Road, Handsworth, Birmingham.
Nov. 3rd, 1894. W. J. Harrison, Jun.

GLACIAL GEOLOGY.

Sir,—Although I scarcely think that Sir H. H. Howorth's letter, published in your November Number, calls for any remark from me, I cannot refrain from noticing a few of his arguments, as they reflect strongly upon his controversial methods.

It is an *impertinence*, it would seem, for me to say anything about Switzerland and its glaciers, or to look at them, seeing that others have already been there, and that a whole library was written upon the subject before I was born! Indeed, it was an unjustifiable public advertisement to say that I had ever been there or had even seen a glacier! At the same time he regards it as *preposterous* that "those who have never studied the mechanics of ice in a laboratory, and, what is more strange, have never seen a glacier at all," should write upon the subject. There is clearly no way out of the difficulty; I must do something preposterous or be impertinent, if I am legitimately to interest myself in glacial matters!

His answer to the demand I made for a statement of the angle of slope at which a glacier ceases to flow is equally characteristic. We learn that Forbes "collected considerable evidence to show what the least angle is upon which ice will begin to move. This is the slope, *the least slope*, available." In other words it is "as much again as half."

We also learn that although the Antarctic continental ice may move into deep water, and present a vertical wall of ice to the ocean 450 miles long and more than 150 feet high, to imagine that con-

tinental Arctic ice can do the same thing required "the invention of Croll, who, sitting in his arm-chair, and endowed with a brilliant imagination, imposed upon sober science the extraordinary postulate"; and the sober, simple, scientific explanation of every difficulty, imagined or real, is that the upheaval of "the highest masses of land on the earth, including the massive mountains of Asia and the American Cordillera," was "very rapid, if not sudden," and that "the breaking up of the earth's crust at the time, of which the evidence seems to be overwhelming, necessarily caused great waves of translation to traverse wide continental areas." His own words, "no science but long-suffering geology would tolerate the absurdity," seem more to the point here.

There need be no loss of temper or heated argument on the subject. Neither dogmatic assertion nor the weight of authority will ultimately prevail. In the eyes of many it may be impertinent of me to have opinions on this or any other subject; but all, it seems to me, have a right to add their mite in the hope that it will assist in the elucidation of the truth. Of one thing I am sure, and that is, that although we have been preceded by Forbes, Agassiz, Bishop Rendu, Ramsay, and Tyndall, and a host of others who have ceased to work in this world, there still remains very much to be done.

10, Charnwood Street, Derby. R. M. Deeley.

THE "SOUTHERN DRIFT."

Sir,—I am sorry that in my paper there should have been any statement which Prof. Prestwich or anyone else could consider misleading. In mentioning the name of Prof. Phillips, as well as that of Prof. Prestwich, in connection with the Southern Drift, my only object was to afford information to those unacquainted with the literature of the subject. I suppose I put Phillips first because the date of the work referred to (1871) was earlier than the quoted paper of Prof. Prestwich.[1] But no one who is at all acquainted with Geology, or even with contemporary history, can suppose that the slight reference in Phillips's work bears any sort of comparison to the full and exhaustive work of Prof. Prestwich, who has done more than any other geologist to create an interest in the once despised "superficial deposits." Nor is it any disparagement of Prof. Phillips's reputation as a geologist that his treatment of these deposits in the Thames district should be necessarily imperfect, and to some extent based on information supplied by others. It is evident that he knew of a hill-gravel formed by "currents from the south transporting flints and sarsen-stones"; but the passage quoted by Prof. Prestwich contains all that he has said on the subject in the work referred to. He has also figured neolithic forms as "Implements from the drift."

[1] Prof. Prestwich writes:—"This is a mistake. Prof. Prestwich's first paper on this subject was published in 1847. Besides, flint, gravel, and sarsen-stones *alone* do not prove a drift from the south. It might as well have been from the west or north-west."—J. P.

I hope, therefore, that Prof. Prestwich will accept my assurance that I had no intention of suggesting that he was in any way indebted to Phillips. I regret also that my reference to the Weald is not sufficiently clear; I said: "It is open to question whether the Weald ever had the character of a mountain-region." The question which I was considering was whether stones are ever worn by the action of torrents so as to produce a groove in one side, and I placed the remarks quoted above in a footnote. Of course the Weald must at some time have been a region of comparative elevation; but considering the nature of the materials of which it was composed, and that denudation must have gone on during the period of gradual elevation, it appeared to me permissible to doubt whether it was ever a mountain-region in the sense in which, for instance, the district of Snowdon is a mountain-region; that is to say, a region giving birth to numerous torrents.

But in any case the argument in my paper would not be affected; and I have certainly no wish to raise a controversy on a matter in regard to which Prof. Prestwich knows far more than I do.

THORNDALE, CRAVEN ROAD, READING. O. A. SHRUBSOLE.

MOUNTAIN-MAKING BY TENSION.

SIR,—Mr. Vaughan "having stated a new theory to account for the inequalities of the Earth's Surface," and this theory being dependant upon the tensile strength of the Earth's crust, I suggested that he should favour us with some proof that the outer shell of the Earth is sufficiently strong to do the work demanded of it. He observed in his first paper,[1] "It obviously follows that the outer shell exerts a squeezing force upon the interior, and by compressing the mass into a smaller volume increases its density." In my communication to this MAGAZINE[2] I pointed out that no tensile stress that the Earth's crust could stand would be sufficient to compress the materials of the interior of the Earth, stating in effect that if the outer shell is assumed to be 30 miles thick, and of the tensile strength of steel, it could not exert a pressure of half a ton per square inch upon the interior without fracturing.

Mr. Vaughan now says that he does not rely upon decrease of volume due to pressure, but "upon the *transference* of material from beneath a surface of great pressure to below a surface upon which the pressure is much less." This is not very different to what I understood of his theory from his first paper, and my calculation was given merely to show what an exaggerated view Mr. Vaughan held of the compressive powers of a contracting crust. Mr. Vaughan's theory, so far as I can understand it, appears to be this:—Mountain Ranges are produced by the differential tensile stresses of a shrinking crust causing a local flattening of the Earth's curvature, and thus compelling a flow of material from where the crust is strong enough to prevent, to where it is weak enough to permit of, bulging. Now, on the assumption that a shell of steel 30 miles thick represents the tensile strength of the contracting crust—an exceedingly liberal

[1] GEOL. MAG. 1894, p. 264. [2] *Ibid.* p. 414.

estimate—the maximum effect, leaving out of account internal friction, would be equal to raising a column of rock 1000 feet above the normal of the Earth's surface; but, when we come to consider a local contraction of the crust, we have an exceedingly complex problem to deal with. Each section of the spherical shell, such as we have assumed, would initially possess tensile strength sufficient to put the same pressure per square inch upon the interior of the sphere that the whole shell would; but, as the area became flattened by contraction, its power of compression would become proportionally less. Taking this into consideration, together with internal friction, in small areas the elevatory effect by transference of material would become infinitesimal.

If this reasoning be true, and I believe it to be so, Mountain-Making by Tension is an impossibility. It will not account for either the shape, height, bulk, or linear direction of Mountain Ranges as we know them, much less the compression and folding most of them have undergone. We are thus thrown back upon some theory of compression would we account for mountain-structure as seen in Nature.

Before concluding, I would point out that, in addition to these quantitative deficiencies, Mr. Vaughan's theory seems to involve a mechanical contradiction. If the tensile strength of the contracting crust were great enough to do the required work, a strong enough anchorage would be needed at the boundaries; whereas by the hypothesis this is the weak part, otherwise it could not be elevated by material forced to flow under it from below the contracting area. It seems to me very like the case of a man trying to lift himself up by pulling at the chair he is sitting upon.

Park Corner, Blundell Sands, Liverpool. T. Mellard Reade.

OBITUARY.

WILLIAM TOPLEY, F.R.S., F.G.S.

Born March 13th, 1841. Died September 30th, 1894.

(With a Portrait.)

William Topley was born at Greenwich, on March 13th, 1841; and after gaining his early education at local schools, he received, during the years 1858–61, the valuable scientific and practical training of the Royal School of Mines.

In 1862 he was appointed an Assistant Geologist on the Geological Survey, when Murchison was Director-General, and Ramsay was Local Director for Great Britain. He then commenced field-work under the guidance of Dr. (now Professor) Le Neve Foster, who, with others, was engaged in the Survey of the Wealden area. There he was initiated into the methods of geological mapping among the changeful Hastings Beds, at Mayfield and other places between Burwash and Lindfield, to the south of Ashdown Forest. There, too, in course of time, he gained a detailed knowledge of the Cretaceous and Neocomian formations, and his interest was aroused in questions of Physical Geology, to which for many years he gave particular attention.

Yours truly
Wm Ripley

In conjunction with his colleague Dr. Foster he made a study of the superficial deposits over a large part of the Wealden area, and more especially of the gravels of the Medway valley; and together they elaborated in 1865 the well-known paper in which they brought their knowledge to bear on the vexed subject of the Denudation of the Weald. In this essay they gave numerous facts and new arguments to prove, what had in general terms been taught by Ramsay, that the main features of the ground were sculptured by the agency of rain and rivers.

On the completion of the Geological Survey of the Wealden area, the preparation of the descriptive Memoir devolved upon Mr. Topley. Other colleagues, Mr. F. Drew, Mr. C. Gould, and Dr. Foster, who had mapped large portions of the region, had resigned their official positions; but Mr. Topley had had numerous opportunities of becoming generally acquainted with the entire district. How carefully his Memoir was written, and how exhaustively (so far as our knowledge then existed), is known to every geologist. The book, which was published in 1875, at once became the standard work of reference; for, apart from its original information, it gave evidence, as did all his writings, of a thorough study of the publications of other observers, and a full acknowledgment of all they had done.

Meanwhile Mr. Topley had been instructed to proceed to the Coal-field of Northumberland and Durham, and much of his literary labour connected with the Memoir had to be performed in that northern region in the winter time, or at other seasons when field-work was impracticable. In 1868, after six years' service, he had been advanced to the rank of Geologist on the Geological Survey —promotion in those earlier days being far more rapid than at the present time.

When, in 1872, the Committee of the Sub-Wealden Exploration commenced their active operations near Battle, Mr. Topley was, of course, specially interested. He was one of the first to be consulted, and, later on, he was expressly sent by the Geological Survey to the locality, to examine and report upon the cores brought up by the boring-apparatus. He was thereby enabled to record, in his Memoir on the Geology of the Weald, particulars of the strata and their fossils to a depth of over 1000 feet. The classification of the strata given in that work was subsequently modified, and Mr. Topley from time to time contributed many reports and other articles on the subject (see Appendix).

A considerable portion of Mr. Topley's sojourn in the north was spent at Rothbury, near Morpeth, and at Alnwick, where his studies were directed mainly to the Carboniferous rocks and to the Glacial Drifts. The nature of that great sheet of basalt known as the Whin Sill, also engaged his attention and that of his friend and former colleague, Prof. Lebour, and the result of their observations was to prove its intrusive character.

The subject of Denudation never ceased to interest Mr. Topley, and when, during the early years of the GEOLOGICAL MAGAZINE,

many warm discussions took place concerning the origin of escarpments and other features, he joined in the fray on behalf of subaërial agents. In confirmation of views that had been expressed with regard to other regions, he pointed out how in East Yorkshire anticlines, by their fissured summits, had been readily acted upon by inland agents of erosion, whereas, in certain cases, synclines had better withstood the assaults of rain and rivers.

In 1880 Mr. Topley was called upon to abandon his field-work in Northumberland in order to superintend the publication of Maps and Memoirs at the Geological Survey Office in Jermyn Street. This post, which for many reasons was congenial to him, he continued to occupy; and on the retirement of Mr. Edward Best in 1893, Mr. Topley was entrusted with the entire charge of the office. Throughout this period in London the multifarious duties of the department gave but little opportunity for continuous scientific work: ever busy, he was seldom able to do more than the routine work of the office, but his wide knowledge and experience were always at the service of his colleagues and of others who frequently sought advice and information.

Eager at all times to promote the progress of Geology, Mr. Topley took a leading part in the work of that most useful compendium of geological literature, the Geological Record; and here his extensive acquaintance with bibliography was of great service. Finally, in 1887, he undertook the post of Editor, at a time when the Record was in a somewhat troubled condition, owing to delays in publication. These had arisen, despite every effort made by the untiring and disinterested exertions of the original Editor, Mr. Whitaker. In labour which is arduous, by no means uniformly interesting, which brings but little credit, and is wholly unremunerative, it is far from easy to gain and retain steady-working contributors. Men may come to aid the work; but too often they go after dissipating a small amount of energy in recording titles and making short abstracts of papers. Two volumes, dealing with the literature of 1880–84, were brought out in 1888 and 1889; but, even with the effective help rendered by Mr. C. D. Sherborn, the Geological Record had ultimately to be abandoned.

Mr. Topley joined the British Association at the Meeting held in Brighton in 1872, and was at once made one of the Secretaries of Section C (Geology); and from 1872 to 1888 he served this office during no less than fifteen meetings. He was for several years Secretary of a committee appointed by the Association to report upon the Coast Erosion of England and Wales. He was also for some years a member of the Councils of the Geological Society and of the Geologists' Association. In 1885 he was elected President of the latter body, and during his term of office he prepared the interesting account of "The Life and Work of Professor John Morris," which he read in 1886 in place of an Anniversary Address. The long excursion of the Association for the same year was made to the Ardennes on the frontier between Belgium and France; and this, their second foreign excursion, was one

of singular interest and success. It was organized with the aid of M. Dupont, but the arrangements and direction of the excursion fell largely upon the President, Mr. Topley. In the following year, aided by Professor Lebour, the President conducted the Association to many of the scenes of his former labours in Northumberland. On other occasions he led the Members to some of his old haunts in the Wealden area, and to several localities in and around London.

When the International Geological Congress arranged for a meeting in London in 1888, Mr. Topley (who had attended previous gatherings) was chosen as one of the Secretaries, and then, not only during the meeting, but for a long while before and afterwards, his energies were severely taxed with the many duties he had to perform. One feature of this London meeting was the promptitude with which the printed agenda and reports of proceedings were issued day by day—work that was only accomplished by dint of burning much midnight oil.

In 1885 Mr. Topley had prepared an elaborate Report on the National Geological Surveys of Europe; and he was much interested in the question of an international scheme of colouring for geological maps. He had, in 1881, been appointed to superintend the publication of the British section of the Geological Map of Europe, promised by the International Geological Congress; and in 1888 (conjointly with Mr. J. G. Goodchild) he prepared the excellent little Geological Map of Europe which accompanies the second volume of Prof. Prestwich's Geology.

Thus were his services in constant demand. At one time Agricultural Geology occupied a large share of his attention, and he had gathered together much material bearing on the subject, with the view of publishing a work on Soils in their relation to Geology. Several essays dealing with these matters were printed, and perhaps the most important outcome of his studies in the South-east of England was his paper dealing with the connection between the Parish Boundaries and the great physical features which are dependant on the geological structure. The subject was first brought before the Brighton meeting of the British Association in 1872, and it there attracted very considerable attention. The author showed how the ancient divisions of the land were made according to the water-supply, the soil, and situation; portions of down-land being taken to pasture sheep, the productive tracts for agriculture, and portions of forest-land, whether wood or open glade, for swine and as pasture for cattle.

In later years the subjects of Applied Geology occupied the greater part of Mr. Topley's leisure hours. He had given a good deal of attention to the mode of occurrence of Phosphates; he wrote a report on the geological distribution of Gold and Silver; discussed the schemes for the construction of a Channel Tunnel; and wrote concerning the discovery of Coal in Kent.

The subject of Water Supply, however, more than any other engaged his mind, and it was one on which he was recognised as a leading authority. The needs of Hastings, Tunbridge Wells,

Croydon, Birmingham, as well as of London, and many other centres, large and small, were investigated and reported on by him; and during the sittings of the late Royal Commission on Metropolitan Water Supply he gave most important evidence, besides officially doing much work for the Commission in the preparation of maps and sections for the Report.

Sanitary Science was another branch of the subject to which he had applied his knowledge. He assisted Sir George Buchanan, in 1867, in a Report on the Distribution of Phthisis as affected by dampness of Soil; and in 1890 he was appointed chairman of Section III. of the Sanitary Institute, at the Congress held at Brighton. He then delivered an address on Geology in its relation to Hygiene, as illustrated by the Geology of Sussex.

To the study of Petroleum in its geological aspects he had latterly devoted much time, and he had in view the preparation of a treatise on that subject.

Mr. Topley's published Papers and Memoirs amount to eighty-two in number; his Survey Maps to twenty-one sheets, with three vertical and five horizontal sections, illustrating the Northumberland Coal-field and the Wealden area.

His knowledge, however, was by no means restricted to matters of professional concern. In his early days in the Weald, as Professor Le Neve Foster informs the writer, Mr. Topley was fond of Botany, and the two friends collected many specimens for determination at their field-quarters. At that time, too, he was a great reader of the works of Carlyle. Poetry, again, and the Fine Arts were subjects in which at all times he was greatly interested, and with which he possessed more than an average acquaintance.

Since 1875 Mr. Topley had been Examiner in Geology to the Durham University at the Newcastle College of Science; he also succeeded the late Mr. Bristow as Examiner in Geology to the Science and Art Department.

He was elected a Fellow of the Geological Society in 1862; an Associate of the Institute of Civil Engineers in 1874; and a Fellow of the Royal Society in 1888.

Full of energy until within about three weeks of his death, he had attended the Zurich meeting of the International Geological Congress. There, as an acknowledgment of his services, and a testimony to his wide acquaintance with the subject, the chairmanship of the Committee on Bibliography was offered to him; but this he declined on the ground of insufficient acquaintance with spoken French. Leaving Switzerland he subsequently paid a short visit to Algiers, when serious illness overtook him. He had barely time to reach his home at Croydon, ere he was prostrated, and he finally succumbed to an attack of gastritis on September 30th, 1894.

The record of his life is one of constant and unremitting labour. Yet he was ever cheery, and what was perhaps most noteworthy, however much he was occupied, he was always willing, and without any trace of impatience, to be interrupted.

It is sad to feel that he has left unaccomplished several tasks which he had planned, and which he was peculiarly well fitted to perform; but, nevertheless, he leaves behind him a substantial record of good work done. It is far sadder to think of the loss of a most kindly, amiable nature—of a true friend, whose readiness in helping others too often stood in the way of the fulfilment of his own desires. H. B. WOODWARD.

REV. HUGH MITCHELL, M.A., LL.D.

BORN JUNE 22ND, 1822. DIED NOVEMBER 10TH, 1894.

HUGH MITCHELL was born on 22nd June, 1822, at Aberdeen, where his father held a situation in an ironwork. The son, after attending a private English school, proceeded to the City Grammar School, and afterwards went through the curriculum of Marischal College and University. He was always a diligent student, and graduated Master of Arts in 1841.

Of all the classes he attended none pleased him more than that of Natural Science, then admirably taught by Mr. John Shier, LL.D., a much abler man than the aged Professor for whom he acted as substitute. Hugh gained the second prize, and also distinguished himself highly in the chemical class. In company with the writer of this notice, he subsequently roamed the country for miles round Aberdeen, making Natural History collections. Geology and Mineralogy were his heart's love.

Having studied for the Christian ministry, he was ordained in 1848 to the Free Church of Craig, near the southern shore of the South Esk, in Forfarshire, and not far from Montrose. Many of his congregation were Ferryden fishermen, whom he spiritually benefited and whose affection he retained for the 46 years that he continued in the active discharge of his pastoral duty. He took much interest in the condition of the children, and for more than fifteen years was Chairman of the Craig School Board. Whenever leisure was obtainable, he employed it in prosecuting his scientific researches, but was careful that they should not encroach on his proper duty. Only one slight failure in this respect is remembered.

The "Dundee Advertiser" in a long and appreciative notice of Dr. Mitchell, to which the writer has been much indebted in preparing this obituary notice, puts it on record. We give the details, feeling assured that the one solitary lapse will be condoned, if not even regarded with positive favour, by readers of the GEOLOGICAL MAGAZINE. Mr. Mitchell had walked some miles in July, 1857, to baptise a child in a part of Forfarshire, some distance from his ordinary sphere of labour. On arriving, he found that the father had not returned from his work, so, not to lose time, the minister asked the mother to lend him a hammer, and took his way with it to a quarry. He had previously found ichthyic fragments in Canterland Den, but here, at Farnell, on splitting a slab, he laid bare a small, beautifully distinct, and almost perfect fish. He dropped the hammer, forgot all about the baptism (which he performed, with an apology, a fortnight later), and hied him homeward with his treasure. Sir Philip Egerton named it after him,

Acanthodes Mitchelli. At the same place, the minister afterwards found two more fishes, which were named by Sir Philip, *Climatius scutiger* and *Diplacanthus* (*Ischnacanthus*) *gracilis.* The three species were exhibited in Aberdeen in 1859, in illustration of a paper read by Mr. Mitchell before the British Association at its Meeting in that city. They were afterwards figured in the Tenth Decade of the Geological Survey of England. Another fish called after him is *Pteraspis Mitchelli*, by his old friend James Powrie, F.G.S., of Reswallie, near Forfar, also like himself an ardent collector of Devonian Fishes and Crustacea. Both Sir Roderick Murchison and Sir Charles Lyell sought him out in his country "Manse," and examined his extensive palæontological and mineralogical collections.

In 1874 his *alma mater*, the University of Aberdeen, conferred on him the degree of LL.D.

Last year, being aged and infirm, he obtained a colleague to relieve him of his ministerial duties, and returned to his native city. He desired before his departure to dispose of his collection, and it was ultimately arranged that it should be sent to the British Museum (Natural History), Cromwell Road, London, which was accordingly done. The names of Dr. Mitchell's Old Red Sandstone fish specimens, now in the Geological Department of the British Museum, take up about 6½ pages of the Manuscript Catalogue.

On the forenoon of Saturday, 10th November, 1894, Dr. Mitchell peacefully passed away in his 73rd year, leaving a widow and many sympathising friends to mourn his loss. ROBERT HUNTER.

RICHARD MEADE.

RICHARD MEADE, who was so well known in connection with the Mining Record Office, was born in Dublin, in 1827, and died on the 12th September, 1894, after a few hours' illness. He entered the public service in 1841, in the Drawing Office of the old Houses of Parliament, as an assistant to Dr. Reid, who then had charge of the ventilating arrangements of the Houses of Parliament. Here he received instruction in drawing, and was trained as a Surveyor. In 1853, when Sir Charles Barry assumed the control of the ventilating arrangements, Mr. Meade was transferred to the Mining Record Office in the Museum of Practical Geology, as Assistant Keeper of Mining Records, under the late Mr. Robert Hunt, F.R.S.

Here, in the preparation of the volumes of "Mineral Statistics," he acquired that mastery over facts and figures connected with British mining which enabled him, in 1882, to publish his book entitled "The Coal and Iron Industries of the United Kingdom," an elaborate work,[1] the result of five years' labour, which was recognized as a standard work of reference on the subject.

On the abolition of the Mining Record Office, in 1883, Mr. Meade was transferred to the Home Office, and was appointed Clerk of Mineral Statistics, a position which he held till 1889, when ill-health necessitated his retirement from the service.

[1] Noticed in the GEOLOGICAL MAGAZINE for 1883, p. 324.

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